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OF
NEW HAMPSHIRE

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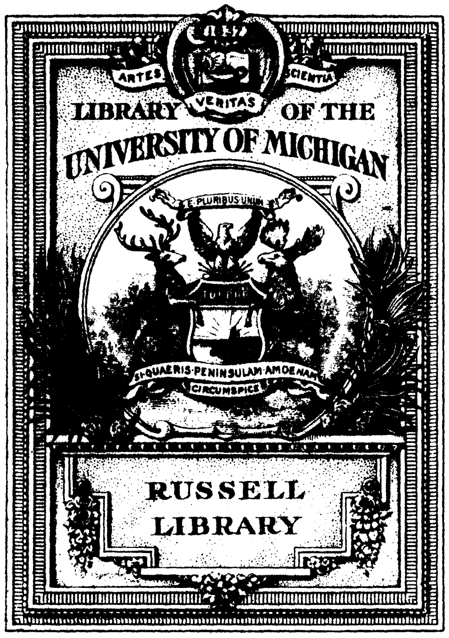

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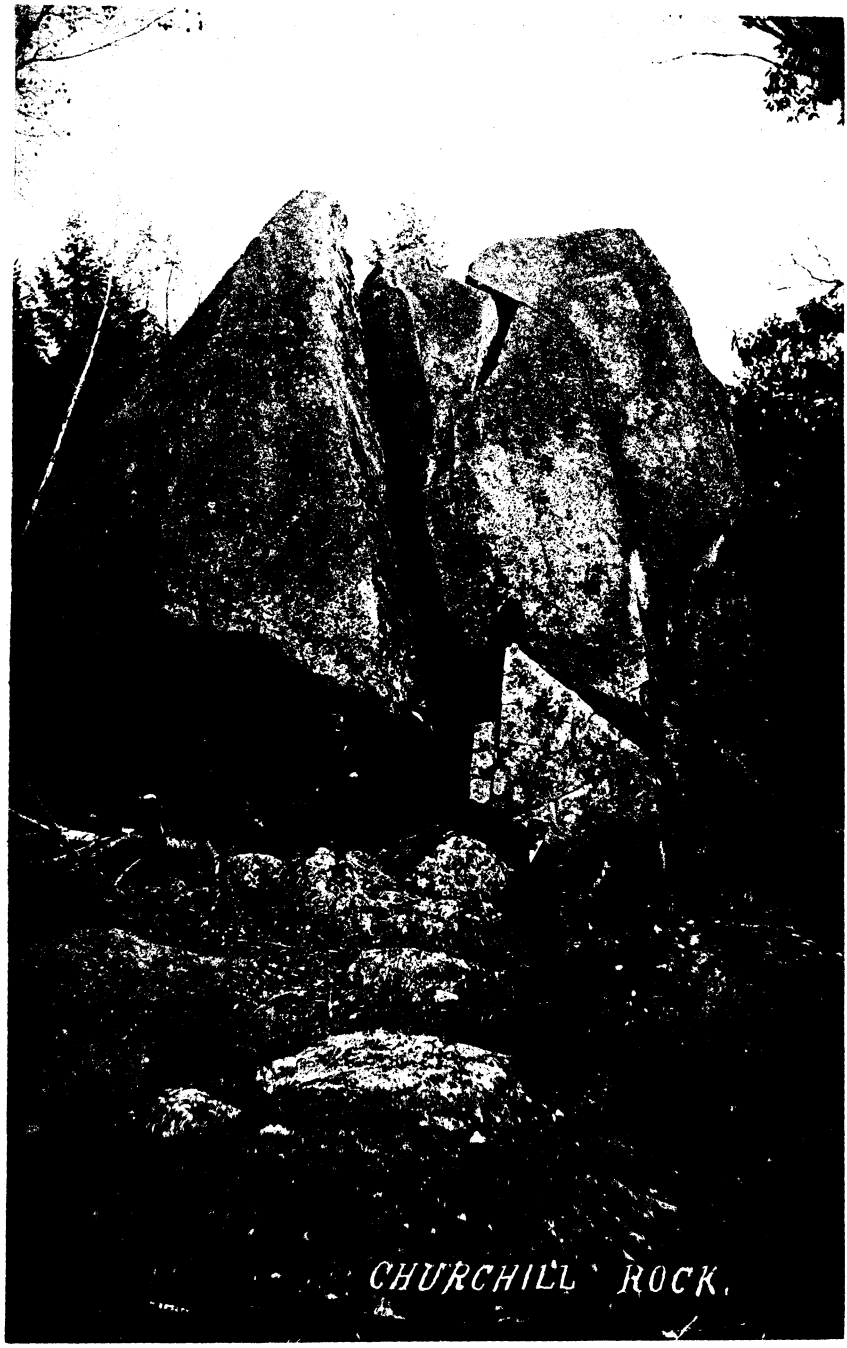
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U. S. Geol. Survey.

THE GEOLOGY
OF
NEW HAMPSHIRE.

A REPORT COMPRISING THE RESULTS OF EXPLORATIONS ORDERED BY THE LEGISLATURE.

C. H. HITCHCOCK,
State Geologist.

J. H. HUNTINGTON, WARREN UPHAM, G. W. HAWES,
Assistants.

PART III. SURFACE GEOLOGY.
PART IV. MINERALOGY AND LITHOLOGY.
PART V. ECONOMIC GEOLOGY.

CONCORD:
EDWARD A. JENKS, STATE PRINTER.
1878.

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PART III.

SURFACE GEOLOGY.

CHAPTER I.

MODIFIED DRIFT IN NEW HAMPSHIRE.

BY WARREN UPHAM.

THE portion of geological history of which we have our principal record in the *Modified Drift*, begins with the departure of the great northern ice-sheet, and extends from that time to the present. The deposits included under this title are the water-worn and stratified gravel, sand, and clay or silt, which occur abundantly in almost every valley in the state. These river-lands comprise the intervals, which are annually overflowed at the high water of spring, and successive terraces which rise in steps upon the side of the valley, the highest often forming extensive plains.

The origin and distribution of these materials present many interesting questions. When the term was first employed, it was the prevailing opinion that modified drift was gradually formed from the unmodified glacial drift by the ordinary action of rain and streams; and similar materials in small amount have been added by these causes, which are still at work. The boulder that is separated from the ledge by frost, and carried forward by the heaviest floods of a mountain torrent, is on its way to form a part successively of the coarse rounded gravel, sand, and silt, over which the river flows on its journey to the sea. It is evident, however, that the high terraces and wide plains bordering our rivers were formed by much greater floods than those of the present time, laden with vast quantities of alluvium. Both the materials and the water for sweeping them into the valleys appear to have been supplied by the melting of an immense sheet of ice. These deposits thus had the same origin with the glacial *drift;* but they have been *modified,* being separated from the coarser portions, and further pulverized or rounded, and assorted in layers, by water.

THE GLACIAL PERIOD.

The indications of a glacial period abound in all northern countries whose geology has been explored; and in New Hampshire they are probably as well shown as in any part of the world. Underlying the modified drift we often find masses of earth and rocks mingled confusedly together, without stratification or any appearance of having been deposited in water. These are the glacial drift or *till.* Unlike the modified drift, till is distributed with no reference to lines of drainage, and frequently covers the slopes or lies at the summits of our highest hills and mountains. The boulders which it contains, or which lie upon its surface, are of all sizes up to ten feet, or rarely even twenty or thirty feet, in diameter; and in this state they have nearly all been transported southward from their native ledges. Where an outcrop of rock is so peculiar that its boulders cannot be confounded with those from other ledges, we may trace them southward or south-eastward, but not in other directions. They are abundant near their source, and diminish in numbers and size as we advance. The till of New Hampshire contains boulders which are thus known to have travelled a hundred miles. Wherever till occurs, it is also found that the ledges have been commonly worn to a rounded form; and, if the rock is sufficiently durable, it is covered with long parallel scratches or *striæ,* which have the same direction with the dispersal of rocks in the till. The same areas are also characterized by extensive deposits of modified drift.

To explain these related facts was a most difficult task, which remained after nearly all other great questions in geology had been settled. The theory which has now been received by most who have studied this subject was first brought out prominently by Agassiz in 1840, and was based upon his studies of the glaciers in the Alps. There fields and rivers of ice several hundred feet in depth are found descending from the regions of perpetual snow, their rate of motion being from one to five hundred feet, or even more in their steepest portions, in a year. Many angular blocks and fragments which fall from the bordering cliffs are carried along on the surface of the ice, or are contained in its mass with others torn from the rocks over which it moves, and under its vast weight these act as graving tools to round and striate the ledges beneath. The similar striation of all northern countries, and the formation of the till, are probably due to a similar cause, namely, a moving ice-sheet which overspread the continents from the north.

This continental glacier had accumulated sufficiently deep to cover every mountain summit in New Hampshire. That it overtopped Mount Washington is fully proved by recent discoveries of the state geologist.* Its thickness farther to the north was so much greater than in this latitude that its immense weight caused the ice to flow slowly outward. The direction of its current in New England was between south and south-east. Its terminal front in the United States coincided nearly with the course of the Missouri and Ohio rivers, passing into the ocean south of Long Island. Its greater extent east of the Missouri resulted from the increased snow-fall of this side of the continent. The termination of this ice-sheet in the Atlantic, south-east of New England, was probably like the great ice-wall bordering the Antarctic continent, along which Sir J. C. Ross sailed four hundred and fifty miles, finding only one point low enough to allow the upper surface of the ice to be seen from the mast-head. Here it was a smooth plain of snowy whiteness, extending as far as the eye could see. The Humboldt glacier, in Greenland, discovered by Dr. Kane, is sixty miles wide where it enters the sea, above which it rises in cliffs three hundred feet high. All icebergs have their origin from glaciers which thus extend into the ocean, being broken off, because of their lower specific gravity, by the uplifting power of the water.

Cause of the Arctic Climate. The conditions which brought on the severe climate of this epoch have been the subject of much speculation and discussion. A theory which, with much probability, refers the ice-sheet to an astronomical cause, and claims to determine the date and duration of the glacial period, was proposed by James Croll in 1864, and has been advocated by James Geikie in his recent work on the *Great Ice Age*. The earth's path about the sun is not exactly a circle, but is a nearly circular ellipse, so that at one point of its orbit it is somewhat farther from the sun than at the opposite point. This eccentricity of the earth's orbit is not constant, but increases and diminishes through long periods. During the past fifty thousand years it has been comparatively small, and will continue so for the same time to come. The last period of great eccentricity began about 240,000 years ago, and lasted 160,000 years. During this time the winters which occurred farthest from the sun, or in aphelion, would be longer and colder than now. The summer's heat would be increased in the same proportion, but it is argued that its length would not suffice to melt the annual accumulation of snow. This would gain slowly in depth, and become solidified, till a large part of this hemisphere would be enveloped in ice. At the same time the opposite side of the globe would have a short, mild winter, and a long, cool summer. Owing to other astronomical causes, known as the precession of the equinoxes and motion of the line of apsides, these different climates would not be permanent for each hemisphere during the whole of this long period, but they would be several times changed, prevailing by turns on each side of the equator. In 21,000 years the hemisphere which at first had its winter at aphelion would have passed through a cycle, in which its place in winter would have traversed the entire orbit,—falling after half this time at perihelion, and finally arriving at its first position. This theory accordingly supposes that an ice-sheet was produced several times about each pole, alternating with long intervals of genial temperature, in which it disappeared. Stratified deposits of sand or clay containing organic remains have been found in Europe, underlaid and overlaid by till, proving the existence of mild inter-glacial epochs. Equally certain proofs of these are rarely found in America. Thick beds of modified drift in the midst of till occur in New Hampshire, but they do not appear to prove a disappearance and return of the ice-sheet.

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*See Chapter II of this volume.

If glacial epochs are produced by a great eccentricity of the earth's orbit, we should also expect indications of ice-action in the older rocks, and probably many coarse conglomerates have been formed in this way. The remote date to which this theory assigns the last glacial period is not improbable, as the amount of erosion effected by Niagara river since the ice age, and other facts bearing on this question, indicate a similar lapse of time. This, however, seems but as yesterday when it is compared with the distant Eozoic and Paleozoic past, in which the rocky strata of New Hampshire were deposited beneath the sea and upheaved in crumpled folds to form our hills and mountains.

The theory of Mr. Croll,* which supposes that during the long period of great eccentricity glacial and warm inter-glacial epochs succeeded each other in cycles of 21,000 years, does not seem to be sustained so fully as we should expect by evidence of such warm intervals, which he thinks even in arctic latitudes would be nearly free from ice and snow. A consideration of what we have to explain by the agency of ice, and of the mode in which these results are likely to have been produced, seems to point to a very long, continuous period of glacial action, with times of retreat and advance, but not apparently of complete departure and return of a continental ice-sheet. By other writers the glacial climate is believed to have been principally caused by a different distribution and elevation of the land, attended with changes in the direction of oceanic currents. Even if a supposed combination of such conditions could be shown to be adequate to produce the ice-sheet, it seems more reasonable to attribute its origin to an astronomical cause, which we know to have existed, with a tendency to bring about these results. As very intense cold is not required for the accumulation and preservation of snow and ice, may not the continually cool climate, when winter occurred in perihelion during the period of great eccentricity, have kept the ice-sheet which was already formed from being melted? The rare testimony of any retreat and subsequent advance of the ice during the glacial period in America, with the vast results which were accomplished in this time, favor this view.

The motion of the ice, being produced by the pressure of its own weight, and extending immense distances over a comparatively level but very irregular surface, must have been exceedingly slow. The average yearly progress of the glaciers of the Alps is about three hundred feet. The continental glacier, which striated the northern United States and Canada, must have had a much less slope. If its upper surface descended only one foot in two hundred, which in this state is considered a very moderate railroad grade, the ice would increase one mile in thickness for every two hundred miles that we advance towards the head of its outflow at the north. Over the highlands between the St. Lawrence valley and Hudson bay it would have been three or four miles in depth, and at the same time probably much deeper over Greenland. Even with this vast accumulation of ice we have so gentle a slope to produce its motion that we can scarcely suppose this progress, at least in its lower portion, which passed over the very uneven surface of the land, to have exceeded one twelfth that of the glaciers in the Alps. This would give us an advance of twenty-five feet yearly, requiring 21,000 years to move one hundred miles. If these conclusions are any approximation to the truth, the highest rate of motion which could be attained by the ice-sheet at its greatest depth, continuing through half of this time, would seem quite inadequate to plough up and remove the extensive and thick deposits of stratified gravel, sand, and clay which we now find in New Hampshire, so that scarcely any traces of them would remain. Similar deposits of modified drift would have been formed at each melting away of the ice; and their almost complete removal in the epochs during which this theory supposes the ice-sheet to prevail seems improbable, when we consider the slowness of its motion.

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* Croll's *Climate and Time*, Amer. ed., pp. 76–78, etc.

The accumulation of the vast thickness of ice which must have existed at the north, probably amounting to twenty thousand feet, seems also to require a longer time than Mr. Croll's theory allows. The average rainfall of New England is about three and a half feet, three fifths of which are evaporated from the surface, while two fifths flow to the sea. This rain-fall exceeds that of the continent northward and westward. Probably it was from a precipitation of snow and rain of no greater amount that the ice-sheet increased in thickness from year to year. Melting and evaporation must have removed a large portion of this; and an annual addition of two feet of ice seems to be too high an estimate. The formation of the ice-sheet would thus occupy all the time through which it is supposed to act in any single glacial epoch.

Another consideration which adds to the probability that the ice-sheet continued through the whole period of great eccentricity, being principally formed in the successive epochs when the winters occurred near aphelion, but not disappearing when winters fell at perihelion, is found in the great elevation of these ice-fields which over the White Mountains reached nearly or perhaps quite to the line of perpetual snow, while farther northward they rose far above this line. The very low temperature which this must cause would seem to make it improbable that the changed proportions of heat received from the sun, such as to produce, if no ice existed, a mild winter and a cool summer, could melt this vast mass of ice and bring a temperate climate in its place. It is certain that this or some other cause partially melted this ice at times, and that it afterwards advanced, covering the territory from which it had retreated; but the work which the ice-sheet accomplished, the length of time requisite for its formation, and the low temperature of the altitude to which it reached, render it improbable that it was several times wholly melted away, alternating with warm inter-glacial periods. The view here taken is, that the glacial period was principally produced by the last great eccentricity of the earth's orbit, the changed proportions of heat received from the sun in the different seasons of the year favoring the accumulation and preservation of vast sheets of ice, which existed in the northern and southern hemispheres at the same time.

Formation and Distribution of Till. The till or coarse glacial drift was produced by the long-continued wearing and grinding of the ice-sheet. As this slowly advanced, fragments were torn from the ledges, and a large part of these were sooner or later held in the bottom of the ice, and worn to small size by friction upon the surface over which it moved. The resulting mixture formed beneath the ice is variously called the ground moraine, boulder-clay, or *Lower Till.* It consists of smoothed and striated stones, with fine detritus, which is usually a gravelly clay of dark bluish color, being always clayey, dark, and very hard and compact. The characteristics of the lower till are due to the mode of its formation. Most of its pebbles and boulders are glaciated, having rounded edges and smoothly-worn sides, which often retain striæ. These show that the finer material in which they occur has been produced by the slow grinding up of these stones under the ice. The dark and usually bluish color is due to seclusion from air and water during its formation, as pointed out by Torell, leaving its iron principally in the form of ferrous silicates or carbonates. Its compactness and hardness are due to compression under the great weight of ice. Because of this quality, the lower till is commonly known as "hardpan."

While this deposit was thus accumulating beneath the ice, great amounts of material, coarse and fine, were swept away from hill-slopes and mountain sides, and afterwards carried forward in the ice. When this melted, a large portion of the material which it contained fell loosely upon the surface, forming an unstratified deposit of gravelly earth and boulders, which may be called the *Upper Till.* There is almost always a definite line of separation, at a depth varying from two or three to fifteen or twenty feet, between the upper and lower till. It will be seen that the upper member is the one usually exposed at the surface, and it is often the only one present where only a thin covering of till is found. Its characteristics are the larger size of its boulders, which are mostly angular and unworn, and commonly derived from less remote localities than the glaciated stones in the lower till; the yellowish or reddish color of its fine detritus, produced by the hydrated ferric oxide to which its iron has been changed by exposure to air and water; and the comparative looseness of its whole mass. This division of the till into two members, which is very well marked throughout New Hampshire, is also conspicuous in Sweden and other parts of Europe; and the peculiar features of each have been recently pointed out by Dr. Otto Torell, of Sweden,* in nearly the same terms here used.

The distribution of the till in this state and in eastern Massachusetts is quite irregular. Sometimes no considerable accumulations of it are seen for several miles, and the ledges lie at or near the surface. Elsewhere the till occurs in large amount, covering the ledges which are scarcely exposed over some whole townships near the coast. Wherever it is found plentifully, it is to a large extent massed in peculiar oblong or sometimes nearly round hills, which usually have quite steep sides and gently sloping, rounded tops, presenting a very smooth and regular contour. These hills are of all sizes up to one third or one half mile long, with two thirds as great width; and their longest axis is most frequently north-west to south-east, coinciding nearly with the current of the ice-sheet. Their height varies from forty or fifty to two hundred feet. These accumulations of till are most abundant near the coast, where they sometimes occupy nearly the whole territory for many miles, while adjoining areas on each side may be nearly destitute of surface deposits, showing only naked, striated ledges. The peculiar distribution of the till, the dispersal of boulders, the course of striæ, and other topics connected with the unmodified glacial drift, will form the subject of the next chapter of this report. Having taken this brief view of the glacial period, we are now prepared to understand the origin of the modified drift.

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* *Proceedings of American Association for the Advancement of Science*, vol. 25, 1876.

THE CHAMPLAIN PERIOD.

The departure of the ice-sheet was attended with a comparatively rapid deposition of the abundant materials which it contained. It is probable that its final melting took place mostly upon the surface, so that at the last great amounts of detritus were exposed to the washing of its innumerable streams. The finer portions of these materials would be commonly carried away; and the strong current of the rivers which would be formed near the terminal front of the ice-sheet could transport coarse gravel, or even boulders of considerable size. When the glacial river entered the open valley from which the ice had retreated, or in the lower part of its channel while still walled on both sides by ice, its current was slackened by the less rapid descent, causing the deposition, first, of its coarsest gravel, and afterwards, in succession, of its finer gravel, sand, and fine silt or clay. The valleys were thus filled with extensive and thick deposits of modified drift, which increased in depth in the same way that additions are now made to the bottom-land or interval of our large rivers by the annual floods of spring. The portion of the material contained in the ice-sheet which escaped this erosion of its streams formed the upper till. The abundant deposition of drift, both stratified and unstratified, during the final melting of the ice-sheet, has been brought into due prominence by Prof. James D. Dana,* who denominates this the *Champlain period*, deriving the name from marine beds of this era, which occur on the borders of Lake Champlain.

The retreat of the ice-sheet was towards the north-west and north; and wherever the natural drainage was in the same direction, it would be for a time obstructed by the ice, forming lakes in which the deposition of modified drift would be much different from that which took place where the slope was to the south. In New Hampshire, the portion of the Contoocook valley which extends through Hillsborough county was thus occupied by a lake during a large part of the Champlain period.

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* *American Journal of Science*, Third Series, vol. v, p. 198, and various papers in vol. x.

Kames. The oldest of our deposits of modified drift are long ridges or intermixed short ridges and mounds, composed of very coarse water-worn gravel, or of alternate layers of gravel and sand irregularly bedded, a section of which shows an arched or anticlinal stratification. Wherever the ordinary fine alluvium also occurs, it overlies, or in part covers, these deposits. Similar ridges of gravel have been often described by European geologists, under the various names of *Kames* in Scotland, *Eskers* in Ireland, and *Åsar* in Sweden. The first of these names will be adopted in this report. They have also been described by geologists in many portions of the northern United States. In New Hampshire, kames are of frequent occurrence, sometimes a single one extending in a very steep, narrow ridge for miles along the lowest portion of a valley, or elsewhere short and several parallel to each other, or in very irregular mounds and ridges, with hollows enclosing small ponds. Their position is generally along the middle or lowest part of the valleys, which are bordered by high ranges of hills; but in the south-east part of the state, in some parts of Maine, and in eastern Massachusetts, where there are only scattered hills with the valleys not much below the general level of the country, these ridges, of smaller size than in the great valleys, are found extending usually north and south, without special regard to the present water-courses. In the valleys of our two largest rivers, the Connecticut and Merrimack, they extend long distances, but had heretofore escaped notice, owing to the large amount of levelly stratified alluvium, forming the conspicuous terraces and plains by which the underlying kames are often nearly concealed. Before this later alluvium was deposited, a kame had been formed in the Connecticut valley, which extended for many miles in a single continuous ridge, from one hundred to two hundred and fifty feet high, with steep sides; and in the Merrimack valley a continuous series of kames had been formed, consisting sometimes of a single ridge, and again of several parallel to each other. Another interesting series of kames extends from Saco river to Six-mile pond, and from Ossipee lake south-easterly along Pine river, and by Pine River and Balch ponds into Maine. The first description of any of these ridges in America appears to have been given by Dr. Edward Hitchcock in 1842,* respecting a series which is well shown in Lawrence and Andover, Mass. Short kames, and small areas occupied by a confusion of gravel ridges and mounds, but not connected with any extended series, are also frequently found.

The origin of the kames has been a question much discussed by European geologists, and the theory commonly accepted on both sides of the Atlantic was, that they were heaped up in these peculiar ridges and mounds through the agency of marine currents during a submergence of the land. Even if such ridges could be formed by this cause under any circumstances, it seemed impossible to account thus for the kames in the Connecticut and Merrimack valleys, which, being bordered on both sides by high hills, would have been long estuaries open to the sea only at their mouths, and therefore not affected by oceanic currents. From the position of these peculiar accumulations of gravel, which are overlaid by the horizontally stratified drift, the date of their formation is known to be between the period when the ice-sheet moved over the land and that closely following, in which this more recent modified drift was deposited in the open valley from the floods that were supplied by the melting ice. We are thus led to an explanation of the kames, which seems to be supported by all the facts observed in New Hampshire, and which appears to apply, also, to the similar deposits which have been described in other parts of the United States and in Europe. During the melting of the ice-sheet it became moulded upon the surface, by this process of destruction, into great basins and valleys; and at the last the avenues by which its melting waters escaped came gradually to coincide with the depressions of our present surface. These lowest and warmest portions of the land were first uncovered from the ice; and as the melted area slowly extended into the continental glacier, its vast floods found their outlet at the head of the advancing valley. This often took place by a single channel, bordered by ice-walls, as was the case along the whole Connecticut kame; but in the Merrimack valley, and in eastern New Hampshire and Massachusetts, these glacial rivers also frequently had their mouth by numerous channels, which were separated by ridges of ice. In these

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**Transactions of the Association of American Geologists and Naturalists.*

channels were deposited materials gathered by the streams from the melting glacier. By the low water of winter layers of sand would be formed, and by the strong currents of summer layers of gravel, often very coarse, which would be very irregularly bedded, here sand and there gravel accumulating, and without much order interstratified with each other. Sometimes the melting may have been so rapid that the entire section of a kame may show only the deposition of a single summer, which would then be very coarse gravel without layers of sand. When the bordering and separating ice-walls disappeared, these deposits remained in the long ridges of the kames, with steep slopes and irregularly arched stratification. Very irregular short ridges, mounds, and enclosed hollows resulted from deposition among irregular masses of ice.

The glacial rivers which we have described appear to have flowed in channels upon the surface of the ice, and the formation of the kames took place at or near their mouths, extending along the valleys as fast as the ice-front retreated. Large angular boulders are sometimes, but not frequently, found in the kames, or upon their surface. They appear to have been transported by floating ice. Their rare occurrence forbids the supposition that these deposits were formed in channels beneath the ice-sheet, from which many such blocks would have fallen upon the kames.

The necessity of referring the formation of the gravel ridges to glacial rivers became apparent during the exploration and study of our modified drift in 1875; and in August, 1876, this was announced in a paper "On the Origin of Kames or Eskers in New Hampshire."* In the revised edition of Geikie's *Great Ice Age*, published in London in the winter of 1876–77, this distinguished glacialist retracts his former opinion that the kames were heaped up by marine currents, and attributes their formation to sub-glacial rivers.† This may be the true explanation in some cases, for such rivers probably existed through the glacial period; but more commonly it would appear, as already shown, that the kames were deposited at the final melting of the ice-sheet in channels formed upon the surface of the ice.

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* *Proceedings of American Association for the Advancement of Science*, vol. 25.

† *Great Ice Age*, second edition, revised, pp. 217, 239, 243, 469, 478, etc. By page 414 it appears that this theory was first proposed by Mr. D. Hummel of the geological survey of Sweden, in 1874; and on page 415 allusion is made to a recent paper by Dr. N. O. Holst, also of Sweden, in which the kames have been explained in the same manner as in this chapter.

Plains and Terraces. The extensive level plains and high terraces which border our rivers, constituting the most conspicuous and by far the largest portion of our modified drift, were also deposited in the Champlain period. The open valleys became gradually filled with great depths of horizontally stratified gravel, sand, and clay, which were brought down by the glacial rivers from the melting ice-sheet, or washed from the till after the ice had retreated, and which were deposited in the same way as by high floods at the present time. The departing ice-sheet was the principal source both of the vast amount of material and of water for transporting it into the valleys, which appear in most cases to have been filled to the level of the highest terraces or plains. The prevailing horizontal stratification of these deposits shows that they were spread over large areas by the current of the floods which held them in suspension. The modified drift thus increased in depth in the principal valleys through a long period, which may have continued until the last of the ice at the head of the valley and of its tributaries had disappeared.

THE TERRACE PERIOD.

During the *recent or terrace period* the rivers have been at work excavating deep and wide channels in this alluvium. The terraces mark heights at which in this work of erosion they have left portions of their successive flood-plains. As soon as the supply of material became insufficient to fill the place of that excavated by the river, a deep channel was gradually formed in the broad flood-plain. The process was very slow, allowing the river to continue for a long time at nearly the same level, undermining and wearing away its bank on one side, and depositing the material on the opposite side, till a wide and nearly level lower flood-plain would be formed, bordered on both sides by steep terraces. When the current became turned to wear away the bank in the opposite direction, a large portion of this new flood-plain would be undermined and re-deposited at a lower level; but the direction of the current's wear might be again reversed in season to leave a narrow strip, which would then form a lower terrace. In this way the Connecticut river, along the greater part of its course on the west border of New Hampshire, has excavated its ancient high flood-plain of the Champlain period to a depth of from one hundred and fifty to two hundred feet for a width varying from one eighth mile to one mile, leaving numerous terraces at each side. The Merrimack and Saco valleys show similar erosion, and it may be seen upon a small scale on every river in the state. On our largest rivers we see the highest plain in some places, and the lower terraces very frequently, being now undermined by the wear of the current, forming steep bluffs and banks. It seems impossible to explain in any different way the cause of the slope, often nearly as steep as is possible for loose materials, which forms the abrupt face or escarpment of level-topped and horizontally stratified terraces. The finer character of the materials which compose the lowest terraces and the interval, or present flood-plain, is due to this wearing away and re-deposition by the river, which have been many times repeated, till what may have been at first gravel becomes very fine sand or silt. By each removal it is made one degree finer, and is deposited at a lower level and farther down the stream. The end of its slow journey is the sea, where it will help to make the sedimentary rocks of this epoch. It has completed a great cycle of changes, ending where the upheaved and contorted ledges from which it was derived had their remote beginning.

Deltas of Tributaries. Upon entering the large valleys, tributary streams of comparatively narrow channel and rapid descent frequently formed extensive deposits in the Champlain period, similar in material to the flood-plain of the main valley, but having a greater height. Sometimes these *deltas*, being partially undermined, form conspicuous terraces a hundred feet above the *highest normal terrace*, which is the remnant of the river's continuous flood-plain. The deposition of the modified drift of the main river was usually but not always to the same level across the valley. The increased supply from tributaries was sometimes a temporary barrier, damming up the waters of the main valley above; and the current could then deposit its sediment principally upon one side, making the highest normal terraces quite different in elevation.

Dunes. Wind-blown banks of sand or *dunes*, apparently isolated on the hillsides, are occasionally found along the east side of Connecticut and Merrimack valleys and south-east of Ossipee lake, at heights varying from the level of the highest terrace or plain to two hundred feet above it. These patches of sand are very conspicuous, because they are often destitute of vegetation, being blown in drifts by the wind. They vary in size, the largest sometimes covering an acre or more, with their thickest portions from ten to fifteen feet in depth. These dunes appear to have been swept up from the broad plains of the Champlain period, before forests had fully covered the land, by the strong north-west winds, which we may suppose prevailed the same then as now. That this is a true explanation of these high banks of sand appears to be proved by the fineness of their material, which contains only particles such as could be carried by the wind; by their frequent occurrence on the east side of the valleys, where they would be formed by the prevailing strong north-west winds, while they are not found on the opposite side; and by the train of sand-drifts usually grassed over, which may be traced down in a north-west direction from the banks of sand now blown by the wind to the normal modified drift. Since the clearing away of the forest, the upper portion of these trains of sand has sometimes been carried several hundred feet onward, and from thirty to fifty feet higher. The excavation of the old drifts has been six or seven feet in depth, as shown by great stumps, beneath which the sand has been swept away. These dunes are ridged, channelled, and heaped up by the wind in the same manner as the more extensive dunes of a sea-coast.

Modified Drift overlaid by Till. About Winnipiseogee lake beds of stratified clay are often found underlaid and overlaid by till. The clay is free from pebbles, and well suited for brick-making. It varies from five or ten to thirty feet in thickness, and occurs at various heights from the level of the lake to three hundred feet above it. The overlying till is from two or three to ten or fifteen feet in thickness, wholly unstratified, and very coarse, containing numerous boulders, which may be five or six feet in diameter. These remarkable clay-beds probably accumulated during the departure of the ice-sheet, in spaces melted under the ice, between it and the lower till.

Modified Drift near the Coast. About Dover, and southward near the sea-coast, thick deposits of modified drift, sometimes forming extensive plains, are found occupying areas of water-shed from one hundred to two hundred feet above the streams, which often flow in wide valleys that are nearly destitute of modified drift. Some of these, as the high plains of coarse gravel and sand about Willand and Barbadoes ponds, near Dover, seem to have been produced by the rapid deposition of materials brought down from the ice-sheet by glacial rivers. At the time of their formation the adjoining valleys were probably still occupied by the unmelted ice. Nearer to the coast we find in this situation beds of fine gravel, sand, or clay, sometimes enclosing marine shells and pine cones, and in several instances overlaid on their north-west side by coarse glacial drift or upper till a few feet in depth, giving evidence of a retreat and subsequent advance of the ice sheet.

Submergence by the Sea. These marine deposits, which reach to about one hundred and fifty feet above the sea, afford the only certain proof found in our exploration of the modified drift in New Hampshire of any change in the relative heights of land and ocean. With the exception of the trunks, branches, and leaves of trees, which have been rarely found, all the rest of our modified drift is, so far as known, destitute of organic remains; and we have seen that the explanation of the thick deposits of the Champlain period, and of their present excavated and terraced condition, requires no submergence by the sea, nor change in the height and slope of the land. It seems quite probable that the submergence in the glacial period, of which we have proof, amounting to fifty feet in southern New England, two hundred feet on the coast of Maine, and about five hundred feet in the valley of the St. Lawrence, was not caused by any downward and upward movement of the earth's surface, but by the attraction of the immense masses of ice, which, as pointed out by Adhémar, would draw the ocean away from the equator towards the poles. The whole amount of water in the sea was diminished, but the accumulation of vast sheets of ice, several miles in thickness, would be sufficient to retain the ocean at its present height near their lower limits, while it would rise much higher than now about the poles, and at the equator would sink far below its present level. Such a rise of the sea, increasing in amount at high latitudes, is attested by the modified drift of both America and Europe; and coral islands afford proof of the corresponding depression of the ocean, succeeded by a gradual elevation to its present height, over large areas within the tropics.

The two great continents appear to have existed, with somewhat the same outlines as now, from a very remote geological epoch. From the Silurian age to the glacial period we have no record that any part of New Hampshire was submerged beneath the ocean; and nearly all that we can say of its history through this vast extent of time is, that it probably had for the most part a temperate climate, and witnessed the same slow succession in its forms of vegetable and animal life of which the coal measures and later rocks in other parts of the United States bear witness. This comparative stability through long ages makes it more probable that these recent changes in the relative heights of land and sea are due to the cause which we have explained rather than to movements of the land.

The exploration of the modified drift in New Hampshire, under direction of the state geologist, was principally made in 1875. In this work on the Connecticut and Merrimack rivers the author had the valuable assistance of William F. Flint, being thus enabled to map all the terraces of these rivers, and measure their heights by an engineers' level. On the Connecticut, this was more conveniently done, and the expense lessened, by employing a boat, which was built by Mr. Flint, for the journey between McIndoe's Falls and Massachusetts line. The particular description of the modified drift of the state will be taken up in the following order: Connecticut river, followed by such of its tributaries as have been examined; Merrimack river, followed by Contoocook river and Winnipiseogee and Squam lakes; Androscoggin river; Saco river and basin of Ossipee lake; basin of Piscataqua river; and the sea-coast.

Modified Drift along Connecticut River.

The sources of Connecticut river, its hydrographic basin, its course and descent on the west side of New Hampshire, and its tributaries from this state, have been described in the first volume of this report.* The territory of Vermont extends to the west shore of this river, but in exploring its modified drift equal attention has been given to both sides. Only by this study of the whole valley could the history of these deposits be discovered, and the portion in this state be understood. A series of maps occupying three plates accompanies the following descriptions. The various terraces which border the river are there delineated, and their heights stated in feet above the sea. The extent and contour of the modified drift is thus shown along the whole valley. Throughout this distance the alluvial area is bounded on each side by high hills, which are only interrupted by the entrance of tributaries.

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* Vol. i, pp. 222–224, 299, 302–305, and 318.

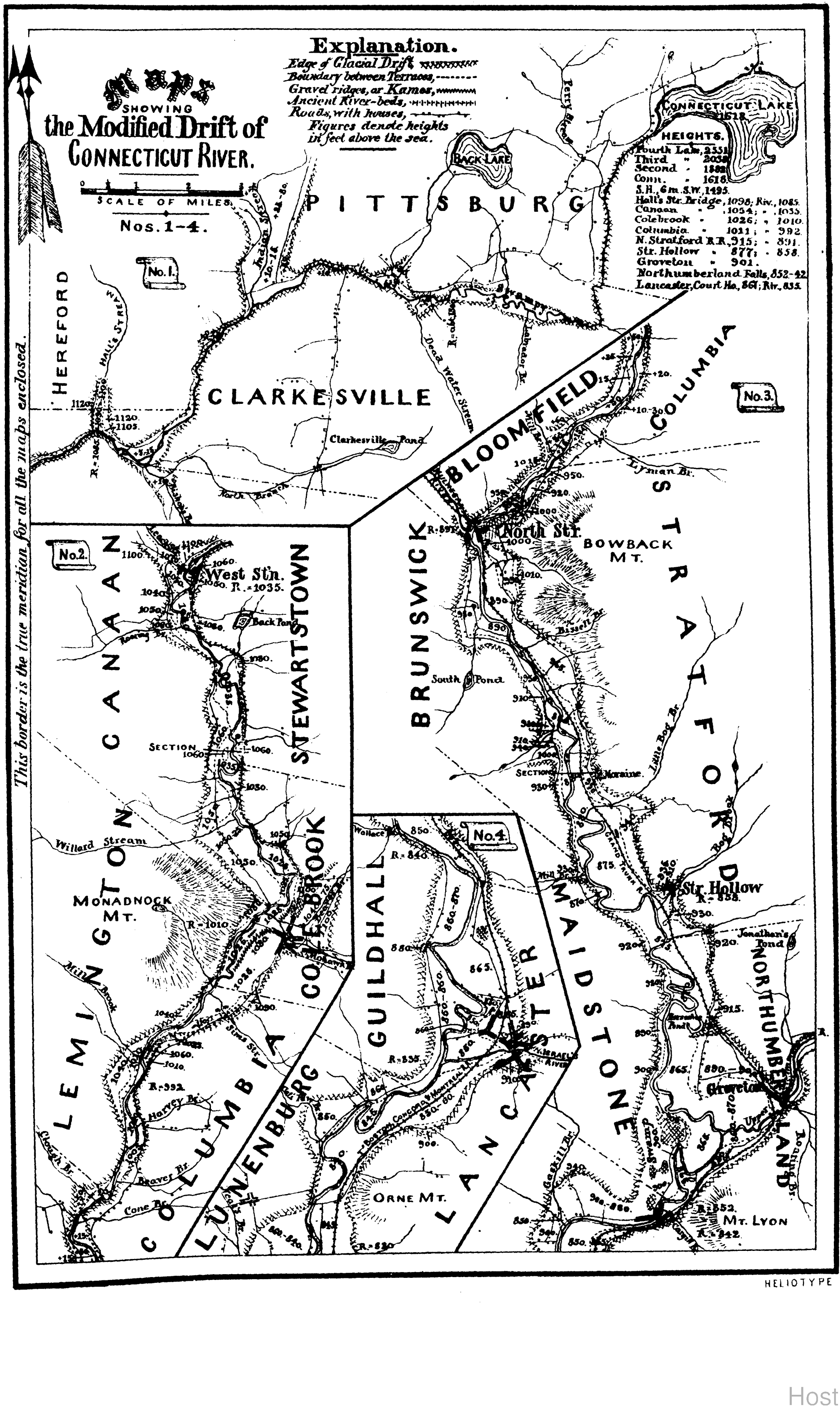
Connecticut Lake to West Stewartstown. For the first four miles below Connecticut lake the river has a rapid descent, with a southerly course. It then bends to the west, and winds with a sluggish current through a narrow swamp three miles in length, which is the first alluvium seen on the river. Its lower end is at the mouth of Deadwater stream. One half mile farther down, at the outlet from Back lake, the road passes over a sand and gravel plain 30 feet above the river. This is material deposited in the Champlain period by the tributary stream. Much of it has been excavated during the terrace period; and till extends to the river on the opposite side in a very gentle, regular slope.

On Indian stream there is a large extent of low alluvial land, comprising several valuable farms. This consists mainly of a wide interval, from 10 to 15 feet high, which is bordered on the east by a narrow lateral terrace from 30 to 40 feet above the river. In the next four miles scarcely anything but glacial drift and ledges is found. The scanty portions which may be called modified drift consist of very coarse, somewhat water-worn gravel, in terraces from 10 to 40 feet above the river, which has probably in many places cut its channel to this depth through the till. About the mouth of Bishop's brook considerable low alluvium occurs, partly brought by the main river and partly by its tributary. Thence we have a narrow width of modified drift on the north side of the river to Hall's stream, which is bordered by an interval from 5 to 10 feet, and two terraces, 20 and 35 feet, above the river. On the south side here, and on both sides for nearly two miles below, the river is closely bordered by hills, and no modified drift is seen.

The portion of the river which we have now described extends southwesterly about eighteen miles from the mouth of Connecticut lake. The descent in this distance is 583 feet. High wooded hills border the valley, which is destitute of modified drift for half of the way. The largest alluvial area is on Indian stream; and the highest terraces are from 30 to 40 feet above the river.

Upper Connecticut Valley. Below West Stewartstown the course of the river is southerly, having a descent in nearly fifty miles, to the head of Fifteen-miles falls in Dalton, of only 205 feet, one half of which takes place in nine miles between Columbia bridge and North Stratford. Along this whole distance the modified drift is continuous, and, including both

Plate I.



HELIOTYPE

sides, is usually a half to a mile and a half wide. It is very simple, having two heights, and consists of the present flood-plain, bordered by remnants of that which filled the valley in the Champlain period. The former is about ten feet above low water, being annually overflowed by the floods of spring. This would be called *bottom-land* in the western United States. In New England it is commonly termed *interval;* but along Connecticut river it is frequently known as *meadow*. On all our large rivers this lowest terrace has a firm and well-drained surface, much different from the marshy areas bordering small streams to which the name *meadow* is restricted in other parts of the state. It is the most valuable portion of these alluvial lands, having a more finely-pulverized and more fertile soil than that of the higher terraces. The ancient flood-plain is here represented by a lateral terrace, from 40 to 120 feet above the river, usually remaining at both sides, and in many places forming considerable plains.

From West Stewartstown to Colebrook the only alluvium of importance on the New Hampshire side is the interval; but small remnants of the upper terrace are found, especially where there is a tributary stream. On the Vermont side the upper terrace, composed of sand or fine gravel, is usually well shown, having a nearly constant but small elevation of 40 to 60 feet above the river, with which it slopes. It appears that this formerly had possession of the whole valley, and that the channelling of the river has swept it away from the area now occupied by the interval or meadows. Portions of it still remain, entirely surrounded by the low flood-plain. Such a plateau may be seen in Canaan, nearly opposite the south line of Stewartstown. The upper terrace and its isolated remnant have both a height of 40 feet above the river, while the lower level is only 15 feet in height. North-east from this in Stewartstown a rivulet has effected a like result on a small scale in the meadow, cutting a channel wholly around a small area which still preserves the height of the rest of the meadow.

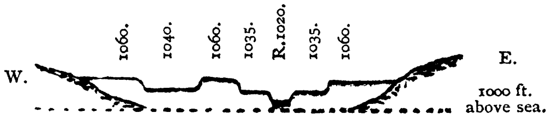


Fig. 1.—SECTION IN CANAAN AND STEWARTSTOWN. Length, ⅔ of a mile.

Kames. At Colebrook we find an interesting gravel ridge or kame, portions of which remain north of the junction of Beaver brook and

Mohawk river, but most noticeably west of the village, extending nearly a mile parallel with the river. Its height is about 70 feet above the river, and 50 above the low alluvium on each side. Its material is the same as that of the long kame farther south in this valley, being principally coarse, water-worn gravel, with abundant pebbles six inches to one foot in diameter. This ridge was deposited in the glacial channel of the river which flowed from the ice-sheet at its final melting.

We must refer to a similar cause the slightly modified drift in Lemington, just north-west from Colebrook bridge; in Columbia, the high gravel terrace north of Sims stream; thence for a mile southward the moraine-like, level-topped or irregular drift, slightly modified, at about 100 feet above the river; and the coarse drift ridge on the east side of the river a half mile above Columbia bridge. The last is a distinct ridge, one third of a mile long, parallel with the river, and from 50 to 75 feet above it, being from 25 to 50 feet above the adjoining lowland. This may have been a medial moraine. It contains many angular rock-fragments from two to three feet in size, and seems scarcely modified, appearing like portions of the kames along Merrimack river.

Between Columbia bridge and North Stratford the descent is rapid and the terraces are irregular. At Columbia bridge the highest alluvial banks are 48 feet above the river; at North Stratford, 119. Where the river now descends 101 feet the stratified drift of the valley shows a slope of only 30 feet, or about three feet to a mile. After we pass this steep and narrow portion, and enter a wide valley again where the river is comparatively level, we find the upper terrace falling much more rapidly, or nine feet to a mile. At Groveton it has again descended to a height 50 feet above the river. As we approach Fifteen-miles falls, the upper terrace slopes very slowly down to the lower, and they can scarcely be distinguished as separate heights below South Lancaster. The wide river-plain here rises gradually from 5 or 10 to perhaps 20 or 30 feet above the river.

In Stratford and Brunswick both heights of the alluvium are well shown, the highway being on the upper terrace and the railroad on the meadow. The former is about 100 feet above the river, and at Brunswick Springs, and for much of the way through Stratford, is from one fourth to one third of a mile wide. At Stratford Hollow depot the railroad has cut through a narrow spur of this terrace, which escaped erosion by water. Here the alluvium of the main valley has been excavated into secondary terraces by Bog brook. In the south part of Stratford, and in Northumberland, the meadow or interval occupies more space than the terrace, which has its greatest extent in the level, swampy plain west of Groveton Junction. In Maidstone, for two miles north from Guildhall, low hills on the west side of the valley hem in extensive swamps, which have been scantily filled with alluvium of nearly the same height with the river terrace.

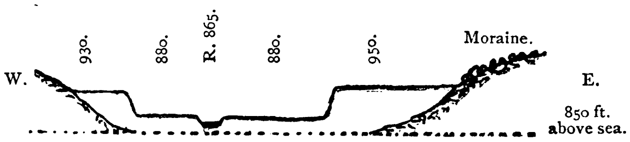


Fig. 2.—Section in Brunswick and Stratford.
Length, ¾ of a mile.

Deltas. At Lancaster the upper terrace of Connecticut river is only 15 or 20 feet above the interval. The only higher modified drift has been brought down by tributaries. Part of Lancaster village is built on one of these deltas, formed by Israel's river on its south side, 50 feet above the terrace of the main valley. This delta sloped rapidly westward, and formerly occupied the whole area of the village; a portion of it, 20 feet lower than the former, remains at the cemetery opposite the court-house. Similar deposits also occur two miles south-west from Lancaster, and on John's river.

Between South Lancaster and Fifteen-miles falls the broad river-plain is unterraced. It seems probable that a lake existed here while the original high plain northward was being deposited. When this was channelled out by the river, so as to leave only terraces as we now see them, the materials excavated were sufficient to fill up the lake. It would be interesting to know the depth of the stratified drift in this basin; it is probably deeper than the height of the highest modified drift northward above the river.

Kame-like materials of small extent were noticed at North Stratford, forming the high bank on the east side of the railroad, one fourth mile south-east from the depot, and in Guildhall, about two miles north from Lancaster bridge. A remarkable moraine of granite boulders occurs in Stratford, covering a large area of hillside just above the upper terrace, one mile south from Beattie's station. Two miles north-west from

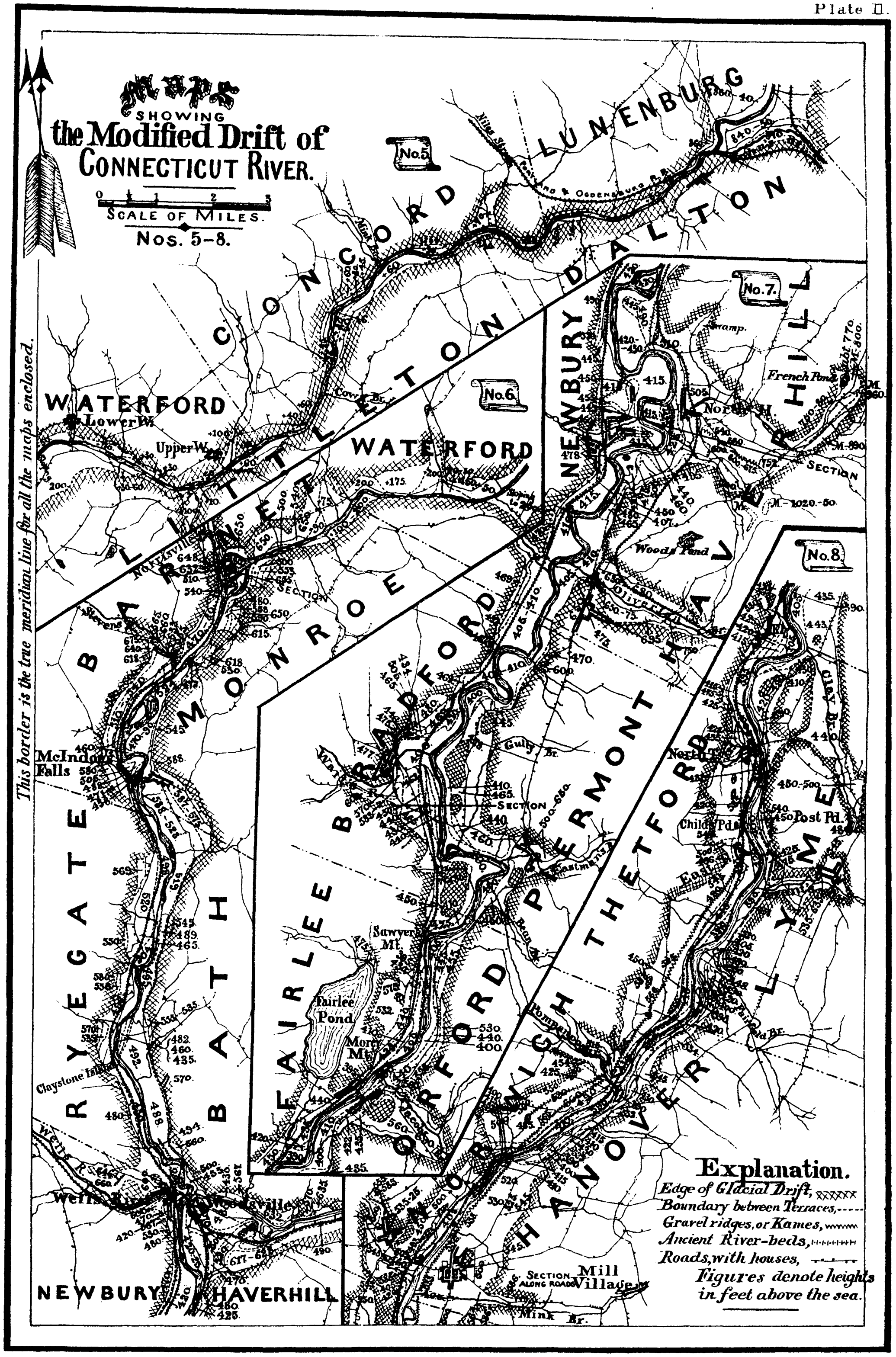
Groveton a ridge of till, from 60 to 100 feet above the river, projects half a mile westerly into the valley, or half way across it, appearing like a terminal moraine. Horse-shoe pond, on the north-west side of this ridge, occupies a portion of a deserted river-channel. These ancient river-beds are frequently shown by such ponds, commonly called *sloughs* or *moats*, of which Baker's pond, near Lancaster, is another example. We see the river now slowly changing its position by wearing away one or the other of its banks, and it has thus swept many times from side to side in excavating its valley between the bordering terraces.

Fifteen-miles Falls. From the mouth of John's river the Connecticut has a rapid descent for twenty miles, amounting to 370 feet, falling from 830 to 460 feet above the sea. The bed of the river is a nearly continuous slope of coarse till, showing abundant boulders, but with scarcely any exposure of solid ledges. The only place where these were noticed in our exploration was at the "lower pitch," or foot of these rapids, about a mile above the mouth of Passumpsic river. Here there is a precipitous fall of a few feet, and this is said to be the only point of abrupt descent. In other parts of its course the falls of the Connecticut are produced by ledges, and the channel, except at such falls, is composed of gravel, sand, or silt. Nowhere else below West Stewartstown, except at the falls of Northumberland and Columbia, and rarely, if at all, southward, does the river flow over the glacial drift or till.

The noticeable features of the valley in this distance are, that it is deep and narrow, with sloping sides of till, and destitute of the level alluvial terraces and intervals which occupy a large width everywhere else along the river. Where any modified drift does occur, it is coarser than usual, being generally gravel, sometimes imperfectly rounded or water-worn, and its surface has commonly an irregular slope. The upper portion of these rapids is especially destitute even of such alluvial deposits, the highest that occur being from 60 to 75 feet above the stream. It is frequently evident that the source of these deposits is not the main river, but a tributary, as in the case of Niles stream in Concord, Vt., and on both sides at Upper Waterford. These deltas are greater in height, as well as in amount, than the scanty remnants of the alluvium of the main valley.

On the lower portion of these rapids the modified drift appears in greater quantity and at a much increased height. Opposite Lower

Plate II.



HELIOTYPE

Waterford we find irregular hillocks of sand, barren of vegetation, and drifted by the wind, the highest of which are about 200 feet above the river. Below this point the modified drift rises in irregular slopes to a height of 200 feet in several places, and its position shows it to have been principally deposited from currents of the main valley. As we approach the foot of the falls its coarse character is changed, and sand predominates in the place of gravel. These deposits probably once filled this part of the valley nearly 200 feet above the present river, sloping in six miles between Lower Waterford and Passumpsic river from about 800 to 650 feet above the sea.

The course of the river along Fifteen-miles falls is S. 70° W., being turned much to the west from its general direction. This course is at right angles to the line of motion of the great ice-sheet; consequently this valley was sheltered from the direct grooving and rasping of the ice, and must be supposed to have furnished a lodgment for much of the ground-moraine or till that accumulated in its track. We have mentioned that this material forms the river channel, nearly everywhere concealing the underlying rocks. It also forms the sides of the valley for most of the way, rising quite steeply from the river, and sometimes presenting a terraced appearance at a height much above the present channel. These considerations lead to the conclusion that the river has excavated much of its present deep, narrow channel through this till since the disappearance of the ice, and since the deposition of its highest modified drift.

The facts observed point to an order of events somewhat as follows: In the ice-age a great amount of till was caught by the transverse valley. At the melting of the ice modified drift was swept into the valley, massing in the largest quantity at its lower end, and deltas were deposited by tributary streams. In some places the wind seems to have blown up sand-drifts to a position on the hillside above the normal height of modified drift. As soon as the melting had receded to a few miles above the head of these falls, further deposition ceased, all the material supplied being retained in the upper valley. The river next began the work of excavation. Most of the modified drift was carried away, and considerable depths channelled out in the till. It does not appear certain that a great amount of till was removed from the head of the falls; at least, nothing seen in the surface geology of the valley above would require such a barrier. The depth of till thus removed must have been variable, sometimes probably amounting to 100 feet; and more or less of this excavation seems to have taken place along the entire extent of these falls. The irregular surface left by the ice has been thus reduced to a channel of nearly regular slope with no abrupt falls, cut through the till, which still covers the ancient bed in which the river flowed before the glacial period.

Lower Connecticut Valley. The early pioneers retained the Indian name *Coös*, which they found applied to the fertile intervals of Lancaster and Haverhill. These were the Upper and Lower Coös, separated by the Fifteen-miles falls. By a similar division, the whole extent below these falls is here called the lower valley. This is comparatively level and straight, with a southerly course nearly the same as that of the upper valley. In a direct distance of 118 miles from the mouth of Passumpsic river to Massachusetts line, the river flows 137 miles, descending from 460 to 180 feet above the sea, or two feet to the mile. The principal falls in this distance are Beard's falls at Barnet, 5 feet; McIndoe's falls, 10 feet; Dodge's falls, three and a half miles south, 5 feet; at Woodsville, about 10 feet; White River falls, 35 feet (see map, vol. i, p. 302); Sumner's or Quechee falls, two miles below the mouth of Quechee river, 5 feet; and Bellows falls, 49 feet,—making a total of 119 feet, and leaving an average descent, excluding falls, of 1⅛ feet per mile.

The modified drift of this lower valley is everywhere well developed, and occurs in extensive terraces of various heights, three or four often on each side, the upper one being usually from 150 to 200 feet above the river, while the lowest is the interval or meadow. The largest plains are expanses of the upper terrace, or of still higher tributary deltas. These areas are generally of a clayey, moist, productive soil, quite in contrast with the dry sandy plains of Merrimack river, Ossipee lake, and other parts of the state. The nearest resemblance to these barren "pine-plains" is found at Woodsville, in the high delta of Lower Ammonosuc river, on the north side of Black river in Springfield, Vt., and in the high, broad plain of Hinsdale. The latter is the only one of these areas which can be compared in size with the extensive plains of central and eastern New Hampshire.

The most extensive intervals or meadows are between Woodsville and Bradford, Vt., 12 miles long and one half to one mile wide, including the Lower Coös intervals of Newbury, Vt., Haverhill, and Piermont; and in Charlestown and Rockingham, Vt., 6 miles long and half a mile wide. But, in addition to these, smaller areas, up to a mile or more in length and a few rods to a half mile wide, are of common occurrence along the entire valley. These bottom-lands are very fertile, being composed of the finest silt, and enriched every year by a coating of mud from the turbid freshets of spring. Many of the lower terraces which are not overflowed are of the same material; but the higher terraces usually show some intermixed sand or fine gravel.

These lateral terraces are less plainly continuous in extent and height than the intervals or the upper terrace. They are sometimes numerous, again wanting; seldom agreeing in height on opposite sides; usually showing a slight slope with the river, but not often more than one or two miles, and generally less than one mile in length, and succeeded by others higher or lower. An examination of them over long distances, however, sometimes shows a well-marked series, descending with the river, and recording a height at which, during the process of erosion, it remained nearly stationary for an unusual length of time, forming a broad and continuous flood-plain, now interrupted and mainly swept away by the further deepening of the channel. These terraces are almost always level-topped, and bounded at the face by a steep escarpment; and their appearance is sometimes very striking, and even grand, as they rise in gigantic steps on the side of the valley, shaped with a smoothness, order, and beauty which could not be surpassed by art.

The greatest widths of modified drift that can be measured in this valley, on the west side of New Hampshire, are in Haverhill and Newbury, two miles, and in Hinsdale and Vernon, two and a half miles wide. The average width is fully one mile. The narrowest places are at Shaw's mountain, near the south line of Bradford, Vt., and at Barber's mountain, in Claremont, both of which occupy the middle of the valley, with narrow belts of alluvium on each side; at the west side of Rattlesnake hill, Charlestown; and at the south end of Wantastiquit mountain, below Brattleborough, Vt. We do not discover, however, at these places, or elsewhere, any evidence of former barriers, which could have made the valley a series of lakes. The vast amounts of modified drift which accumulated in this valley do not appear to have filled ancient lake-basins, but to have been rapidly deposited from the immense floods supplied by the melting of the ice-sheet. These great deposits of modified drift, for which there appears no other adequate cause, should rank with the till, striæ, and embossed ledges, as proof of a former continental glacier.

The Passumpsic river must be considered as occupying the continuation of the lower Connecticut valley, but at its mouth it flows through a rocky gorge, which separates its numerous and high terraces from those of the Connecticut. Four or five terraces are shown here on the Monroe side, the highest 190 feet, and the lowest from 15 to 20 feet above the river. The latter forms the Nine Islands, of which only one is above the reach of high water. This is a wooded island close to the Vermont side, and forms a north and south ridge 50 feet above the river, composed in part of kame-like gravel. Delta terraces from 50 to 60 feet above the highest in the main valley have been brought down by Stevens river, which falls 100 feet in Barnet village. Gleason's islands, one mile below, like nearly all those found in the river southward, are alluvial interval. Several terraces appear at McIndoe's falls, on the widest of which the village is situated, 50 feet above the river. The high terraces do not present a broad level top till we come to Monroe village, where we find two, 100 and 150 feet above the river, both of which are continuous a mile and a half, with regular southward slopes of ten and twelve feet. Occasional remnants of the highest of these are found on both sides through Bath and Ryegate; and the lower is well shown through these towns, agreeing closely in height on opposite sides of the river. On the east side it is continuous for eight miles, from one mile north of Monroe to the Narrows near Woodsville, sloping from 545 to 488 feet above the sea.

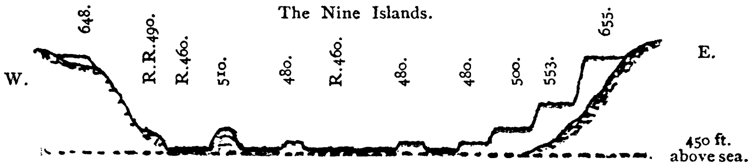


Fig. 3.—Section in Barnet and Monroe, at Mouth of Passumpsic River. Length, 1 mile.

At Woodsville a great depth of material was brought into the valley by the Lower Ammonoosuc and Wells rivers. The former stream has cut its channel 200 feet deep through its delta, wide areas of which still remain on both sides. An old outlet of Wells river may be seen on its north side, one mile above its mouth, occupied at the close of the ice period until it cleared away a hundred feet or more of modified drift from the pre-glacial rocky bed in which it now flows. A well-marked kame occurs here, commencing in Bath half a mile north-west from the Narrows. It has been cut through by the river, and appears on the east side of the railroad at and above the junction, and again at the south-west side of Wells River depot, being more than a mile long. It is composed of coarse gravel and sand, anticlinally stratified, with varying height from 80 to 150 feet above the river. It is well shown by cuttings, but otherwise might escape notice, as most of it is partially or wholly concealed by the ordinary alluvium. In position, material, and stratification, this is like the long kame which extends in this valley from Lyme to Windsor; but in the twenty-four miles from Wells River to Lyme no similar ridge is found.

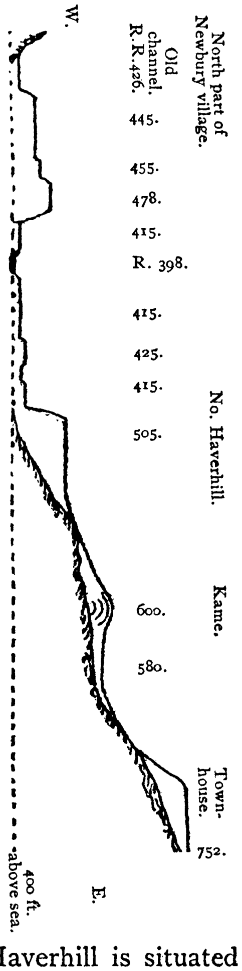


Fig. 4.—SECTION IN NEWBURY AND NORTH HAVERHILL. Length, 4 miles.

From Wells river to Wait's river, at Bradford, the lowest terrace or interval is one half mile to one mile in width; and the river sweeps in broad curves from side to side between its bordering upper terraces. By the largest of these bends, called the Ox-bow, the river traverses two and a half miles to make one half mile of advance, by which a beautiful expanse of interval is added to Newbury. An old channel formerly left this and as much more on its east side. This ancient course extended from the north-west end of the Ox-bow south-west to the railroad, which it followed to the brook that flows through Newbury village, by which it passed east to its present channel. North Haverhill is situated on the highest normal terrace, 107 feet above the river and 27 feet higher than the corresponding terrace opposite, on which Newbury is built. This difference may be partly due to the fact that here was one of the principal outlets of the melting ice-sheet that continued to cover Moosilauke and the high water-shed after it had withdrawn from the Connecticut valley. East from North Haverhill, where there are now only insignificant brooks, we find an abundance of sand and coarse gravel which came from this source. It is disposed in irregular slopes, in some portions mounded or ridged, and rising in about one mile 250 feet, beyond which the same materials extend nearly level to French pond. Taking the road to Haverhill town-house, we pass a ridge of coarse gravel or slightly modified drift, which rises from 40 to 100 feet above the village. North-east from this there is a nearly level plain of fine alluvium, with beds of clay. A short distance farther east we come to a sand ridge, which extends about a half mile along the road, rising 80 feet by a gentle slope, and then abruptly 75 feet more, like the face of a terrace, to a level plain on which the town-house stands, 247 feet above North Haverhill and 752 feet above the sea. This plain, its western steep slope, and the first ridge below are all of sand, with none of the coarse gravel characteristic of kames. Similar deposits of fine material reach for a half mile on each side of this road, sometimes in level plains of small extent, but generally in varying slopes, by which they are continuous from the town-house to the upper terrace of the river.

The remainder of the way to French pond is comparatively level, being at first a plain of stratified, coarse-grained sand, which extends north one half mile to the brook; thence, for a mile and a half farther, sand or coarse rounded gravel extends along the road and on its east side as far north as to French pond. Immediately about this pond the modifying action of water is not apparent, but the surface is composed of heaped and ridged morainic drift, over which the road passes. This material is, however, in the main, level; with irregular hollows and depressions of only ten to twenty feet. Its rock-fragments are angular, but small in size, seldom exceeding two feet. A coarse morainic ridge extends more than a mile on the east side of this level alluvial valley, with a height about 125 feet above it, while on the west rises the precipitous face of Brier hill. Three miles south-east are the serrated mountains which extend north from Owl's Head; and nine miles south-east is the high, massive ridge of Moosilauke.

By estimate, French pond is about 770 feet above the sea, and the water-shed on the road northward is from 40 to 50 feet higher. This hollow, bounded on both sides by high hills, seems to have been for a time the outlet of the melting ice at the north, before the way was opened westward for the Lower Ammonoosuc river. The glacier which covered the mountains at the south-east also contributed to these deposits of modified drift, as is shown by the high moraine mentioned, and by others three fourths of a mile south from the town-house, at the mouth of a gap in the first high range of hills. The highest of these last has been modified by a current of water. It presents on the west side a steep escarpment of clear sand, reaching from 980 to 1020 feet above the sea. At the top this changes to gravel, which becomes coarse as we recede from the edge of the steep slope; next are large glaciated boulders, heaped together with no earth among them, which again present a steep face and somewhat level top 1050 feet above the sea. These rest at the east against the hillside. On the north-west nothing intervenes to the town-house and North Haverhill, 300 and 550 feet below, where we find the sand and clay which were brought down by these glacial streams.

At Haverhill there are only scanty remains of modified drift above the interval, which is nearly a mile wide. The highest terrace, best shown on the Vermont side, is 80 feet above the river; enough of it is left on the east side to indicate that it was once continuous across the valley. Hall's brook and Oliverian brook, which have their mouths here opposite to each other, have brought down large amounts of modified drift, which is deposited along the lower portion of their course. On the former this slopes in one mile to 125 feet above the upper terrace of the Connecticut. On the east side only slight vestiges of this terrace are found, and we have a direct rise of 220 feet from the interval to the modified drift of Oliverian brook, which thus commences at a greater height than is reached in the first mile on Hall's brook. In two miles this slopes upward 100 feet, or to 340 feet above the river, being well shown all the way, and at one place nearly a mile wide. These streams are both of large size, but the deposits along their course cannot be attributed to their ordinary action, any more than the modified drift east of North Haverhill is due to the brooks there. All these deposits are plainly of the same date and from one cause,—the melting of the ice-sheet.

The village of Haverhill is situated on a high, smoothly rounded, terrace-like area of till. This slopes steeply towards the river, but very slightly to the north and north-east, and extends nearly level for half a mile south-east to the foot of Catamount hill, and for two miles southward along the Piermont road. A large proportion of the boulders in this till are glaciated, sometimes preserving distinct striæ. The prevailing size is less than three feet; but rocks of five or six feet diameter, or even larger, also occur. These are found most rarely over the south part of this area in Piermont, where the abundant rounded or glaciated pebbles exposed by the channels of streams present the appearance of coarse kame-like gravel. At about one fourth mile south-west from Haverhill village a gully recently made on a previously smooth slope, at a height about 175 feet above the river, and consequently much above its highest terrace, and 75 feet below the village, showed 15 feet of modified drift resting on till. The surface was 3 feet of coarse gravel, which was succeeded by 12 feet of interstratified fine gravel and sand, obliquely bedded. The stratification here sloped with the present surface, about 10 feet in 100, with the obliquely bedded portions steeper in the same direction. Similar sections of overlying modified drift are shown in many places west and south from Haverhill, but the north and east parts of this area consist only of till. This is the ground-moraine of the ice-sheet, peculiarly massed here in very large amount, resembling the massive rounded hills of the same material, which are abundant near the coast. On the opposite side of the river we find the extensive slope, which rises south from Hall's brook, also composed of till with no outcropping ledges.

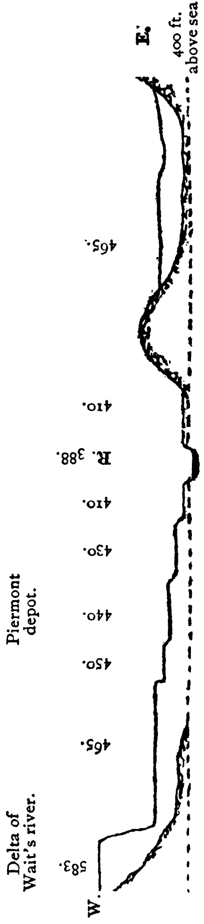


Fig. 5.—Section in Bradford and Piermont. Length, 1¼ miles.

In Piermont, opposite Bradford village, the modified drift is divided by ledgy hills close to the river into two belts, the eastern of which has a height of 478 feet above the sea, or about 90 above the river, where it departs from the main valley. This extends along Gully brook, sloping in two miles to 460 feet, nearly representing in height the normal upper terrace of Connecticut river. We find this normal line shown on the Vermont side by a nearly constant height of this terrace, varying between 470 and 460 feet for more than seven miles, from above Hall's brook to the south line of Bradford.

Delta of Wait's River. We thus exclude, on the north from Bradford village, the principal plain, which is from 10 to 15 feet above this upper terrace, being highest at its south end, and the still higher terrace of the fair-ground, and on the south the conspicuous remnants of the ancient delta of Wait's river, which are more than 100 feet above the Connecticut normal line. These terraces have all been deposited by Wait's river, which seems to have first thrust its high delta into the main valley, whose strong currents undermined and removed a large portion, leaving the rest with a steep escarpment; afterwards most of this delta was channelled out by its parent stream and carried down into the main valley, by which the terraces north of Bradford were formed; and, lastly, it has also swept out a large amount of the upper Connecticut terrace east of the village.

For a mile from the mouth of Wait's river southward, the number of terraces is multiplied to five or six in ascending 75 feet from the river to the wide upper plain. These furnish the best examples seen on the Connecticut of *glacis terraces*, sloping steeply towards the river and gently away from it in a wave-like series, with from 5 to 10 feet difference in the height of successive crests.

Eastman's brook is the source of the modified drift on which Piermont village is built. This delta rises in two thirds of a mile nearly 200 feet above our normal line.

Delta of Jacob's Brook. We now encounter in Fairlee and Orford one of the most difficult problems presented on this river, in the abundant deposit of alluvial sand, which, between Sawyer's mountain and Morey's mountain, forms a high plateau, whose eastern edge overlooks the river, while its western slope descends towards Fairlee pond. The highest portion of this alluvium is 190 feet above the river and 155 feet above the pond. The highest normal terrace is well shown through these towns, varying from 75 to 55 feet above the river, or from 455 to 435 feet above the sea. This terrace appears in Fairlee, at its north line, south-west of

Shaw's mountain; next east below the plateau; southward from Fairlee village and pond; and at Ely station. In Orford it is wide north-west of Soapstone mountain, and the river road runs upon it south to Jacob's brook; in the village it is the terrace at the east side of the street; and from near the mouth of Sawyer's brook it averages one half mile wide for three miles south, leaving the river at the north line of Lyme, and extending along Clay brook nearly level to within one mile of Post pond. All the modified drift above this regular terrace, embracing the plateau east of Fairlee pond, the high terrace in Orford, which begins at the south foot of Soapstone mountain, and the high remnants at each side of Jacob's brook, must be referred to a common origin, being portions of an immense deposit brought down in the Champlain period by Jacob's brook.

This stream drains a large area west and north-west from Cuba and Smart's mountains, flowing through Orfordville into the Connecticut by a north-west course. An uncommon abundance of fine material was supplied from the melting glacier over this area, and the northward flood which transported it was turned up the valley by the vertical wall of Morey's mountain. For a time the accumulation was too great to be cleared away by the current of the main valley, which was filled by this deposit north to Soapstone and Sawyer's mountains. A wide avenue was next cut through this barrier by the Connecticut, which did not complete till a later date the deposition of its own flood-plain, the remains of which we have called its highest normal terrace.

A few measurements of this remarkable tributary deposit will indicate its extent and depth. It filled the valley for more than two miles north from Orford, averaging a mile in width. The ordinary height of the river here is 383 feet above the sea. The highest point of the plateau in Fairlee, a mile and a half north from the mouth of Jacob's brook, is 575; the lowest point where the current swept west across this plateau, one third of a mile south of the former, is 532; on the east side, a mile and a half north from the mouth of the brook, it is 530; and close at its north side, 565. Along its course we also find a large amount of modified drift, rising in a mile and a half to 690, or more than 100 feet above the comparatively level barrier which it had thrown across the Connecticut valley.

A peculiarly contorted band of clay (Fig. 6), in a layer of clayey sand, with regular strata of sand exposed for several feet both above and below, was seen on the north side of a cart-road which ascends the east bluff of the Fairlee plateau, opposite the house of William Childs.

The shores of Fairlee pond are mostly rugged ledgy hills, and scarcely any alluvium has reached them, either from the plateau of Jacob's brook or from inflowing streams. This pond is 35 feet above the river, and is from 40 to 45 feet in its greatest depth, the bottom being principally sand. It seems not to have been filled with alluvium, simply because it was not in the path of the current; and the steep escarpment of the plain bordering its south end is probably due to its undermining waves. Several glacis terraces were noted south-west of Ely station.

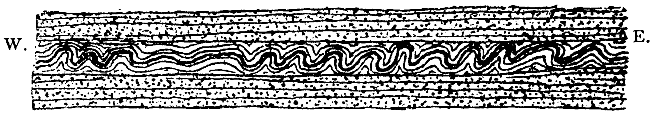


Fig. 6.—Folded Layer of Clay in horizontally stratified Sand, Fairlee, Vt. Scale, 1 inch=10 feet.

In Thetford and Lyme we come to an abrupt change in the height of the upper terrace-plain. We have seen this line descend, in 33 miles between the mouth of Passumpsic river and the south line of Orford, from 650 to 440 feet above the sea, gradually declining from 190 to only 60 feet above the river. At North Thetford this line of the highest terrace suddenly rises to 525, and in a mile and a half farther south to 545 feet. This formation is well shown through Thetford, with remnants in Lyme, and continues well developed and nearly level for twenty-five miles to Windsor, varying from 560 to 500 feet above the sea, and from 150 to 220 feet above the river. It forms extensive terraces or plains on one or both sides along this whole distance, and is clearly the original flood-plain of the river. Frequent delta-terraces rise above it, sometimes 100 feet higher, being more than 300 feet above the present river channel. It is a notable coincidence, that along this same distance we have a continuous kame, occupying the centre of the valley, commonly rising somewhat above the highest plain, but not seldom entirely covered by it. Superposition and conformable stratification show the fine material of the terrace-plain to have been deposited upon this kame or gravel ridge, which beforehand extended like a windrow along the empty valley. To the south from Windsor the highest terrace shows a somewhat regular slope, descending with the river, and preserving a height about 150 feet above it.

This high and continuous flood-plain, extending from Thetford to Massachusetts line, seems to have been formed during a gradual and slow melting of the ice along this distance. It would appear that the greater part of the depth of ice, as far northward as to the Passumpsic river, had been melted in the last part of this time, sending down its floods laden with gravel to form the kame. A comparatively shallow mantle of ice remained, and when the melting advanced to the north from Thetford and Lyme this disappeared too rapidly to give time for the formation of a kame, or the deposition of a high flood-plain.

At the north line of Thetford, near Ely station, the highest terrace is 435 feet above the sea, or 55 feet above the river. This is the south end of the continuous descending slope from the mouth of Passumpsic river. The first intimation of change is a high terrace, which rises from 475 to 545 feet in going from one mile north to one mile and a half south of North Thetford. Opposite to this place in Lyme the alluvium does not appear as usual in distinct terraces, but lies in a slope rising from 400 to 450, and at one mile north to 490 feet. South from North Thetford the high plain averages one half mile wide for eight miles, extending half way through the town of Norwich. Along this distance in Lyme and Hanover only narrow terraces of corresponding height remain.

Child's pond, situated on the high plain one third of a mile north of East Thetford, is worthy of notice. No terrace occurs here below the plain, which has been so undermined as to slope from its top to the river at an angle of 45°, excepting only the width of the railroad bed built on its side near the bottom. Eighty-five feet back from the edge of this plain, with a road between, is the pond, occupying some two acres, 142 feet above the river, and by our soundings 40 feet deep. Its range from high to low water is said to be one foot and a half, with outlet to the west, but no inlet; and its surface is only from two to five feet below the plain on its east and south-east sides against the river. The clayey character of this alluvium is shown by the impervious bank which holds in the pond. The circumstance that only so narrow a width intervenes between the pond and its edge is not specially remarkable, as this plain was originally continuous across the valley, all its east portion having been excavated by the river. The question which we see no satisfactory way to answer is, How came the hollow which contains the pond to be formed or left vacant, when the material of the otherwise nearly level plain was deposited? Probably it marks the site of a mass of ice, broken from the glacier, brought down by the flood, and finally stranded at this spot. The principal objection to this hypothesis is the rapidity of deposition required.

A large amount of modified drift has been brought down by Grant's brook, forming the plain on which Lyme village is built. The common has a slope of fifteen feet, and in a short distance farther east the same deposit rises eighty feet more, to 635 feet above the sea, or 90 feet higher than the water-shed between the village and Post pond.

Ancient River-bed. In Norwich occurs the most interesting example seen by us of a well-marked ancient river-bed high above its present level. This extends two miles from Pompanoosuc river, one third mile above its mouth, to the bend of Connecticut river a half mile south of Tilden pond, which lies in a depression of this old channel. Its highest point, from which there is a gradual descent both ways, is 520 feet above the sea, or 145 feet above the river. West and south-west from this point is a plain, from 30 to 40 feet higher; at the north-west the alluvium forms a delta-like slope with no level top. South-west from Tilden pond the original high plain has been excavated by springs and small streams to a very irregular surface of hillocks and ridges. On the east side of this ancient channel is the steep gravel kame, which for a while turned the Pompanoosuc river in this course, till a direct passage was cut through its ridge.

Norwich village, 525 feet above the sea, is situated on a terrace-plain of Bloody brook, which extends three fourths of a mile above the village, rising 30 feet. At one mile south the modified drift on the Vermont side is interrupted by a ledgy hill.

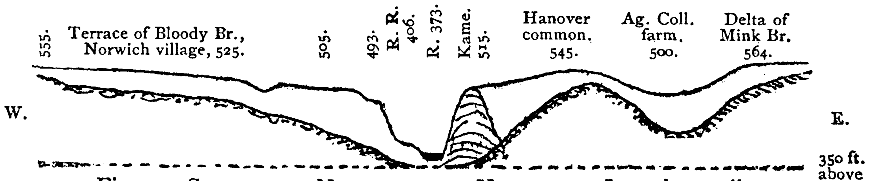


Fig. 7.—SECTION IN NORWICH AND HANOVER. Length, 3 miles.

Two miles north of Hanover the Connecticut river has cut through the kame, and thence flows close on its west side to White River falls. Along this distance of four miles we find the high plain well developed in New Hampshire, averaging three fourths of a mile wide. Hanover common, 545 feet above the sea and 172 above the river, represents its greatest altitude. Westward, a gradual slope descends 30 feet in one third mile to the kame; one third mile east the farm of the agricultural college is 45 feet lower than the common; and we have the same height one mile south, at the highest portion of the road to West Lebanon. Observatory hill, and others in Norwich and Lebanon, are examples of outcropping ledges and till, surrounded by alluvium. Half a mile south-east from Hanover, a delta 20 to 40 feet higher than the common has been brought down by Mink brook, which, west from this point, has also excavated a large amount from the plain. On the roads to Lyme and West Lebanon such erosion as this exposes a *clayey stratum*, noticeable in the spring by remaining muddy after all the rest of the road has become settled and dry. Two miles north of Hanover this stratum appears from 488 to 503 feet above the sea, most notably at the height of 495; a mile and a half south, at the north side of the Vale of Tempe, its height is 482; on the south side, 479 to 482; a mile farther south, on the north side of Mink brook, it appears from 503 to 480, being most marked at 485; on its south side it occurs at two points, with heights 470 and 478 to 483, the last being most prominent; and about a mile farther south, at the descent just before the turn-off to the falls, it is very noticeable, with about the same height. It also occurs in Vermont at a corresponding height, just below the top of the ascent between the depot and Norwich village. This extensive and nearly level stratum shows that deposition took place gradually and at the same time over this whole area.

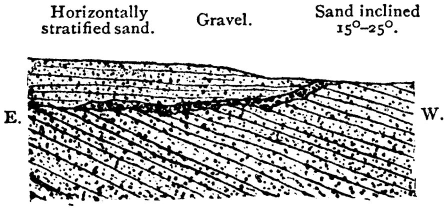


Fig. 8.—Section in Delta of Mink Brook, Hanover. Scale, 1 inch=20 feet.

The lower sand shows the usual stratification of the outer part of a delta, dipping towards the open valley. A current of water has eroded a portion of this, bringing a bed of gravel, upon which rests a later deposit of sand.

In digging the first well at Hanover (near the residence of Prof. H. E. Parker) a large log was found in this alluvium 40 feet below the surface, but no prospect of water, which caused this site, selected for the buildings of Dartmouth college, to be abandoned, and led to their location farther east, upon coarse glacial drift. This log was at nearly the same level with the clayey stratum described, and adds to our knowledge of the conditions which prevailed at the time of its deposition. The glacial age had here been succeeded by a temperate climate, under which forests grew again upon the land; and floods, sent out freighted from the melting ice-sheet, which still remained farther north and on the highlands, brought down drift-wood to be buried with this alluvium. It was not till long after this that the river ceased its work of accumulation and began to cut its present channel.

Veins of segregation in sand, attended in some instances by a slight displacement or fault, are well displayed at the present time by the fresh washing away of the bank, a portion of the high plain, on the south side of the road between Hanover and the depot. These veins abound for 200 feet or so east from the kame, a good section of which is also shown here; they are in somewhat obliquely stratified sand, which inclines conformably where it overlies the side of the kame.

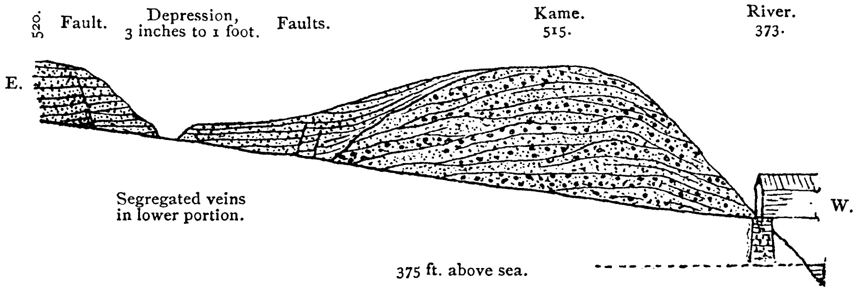


Fig. 9.—SECTION ON SOUTH SIDE OF ROAD, EAST FROM LEDYARD BRIDGE, HANOVER. Length, about 700 feet.

Between Hanover and White River Junction the Connecticut descends 40 feet, principally at White River falls (vol. i, pp. 302* and 319), situated two miles above the mouth of White river, and three miles above that of Mascomy river. An illustration of the terraces on the west side of these falls, as seen from Colburn hill in Lebanon, appears in Dana's *Manual of Geology*.† The upper terrace is wide, with a height 525 feet above the sea, or 190 feet above the river at the foot of the falls. The middle terrace here rises in going south from 435 to 455 feet; and its material, well shown by a long railroad cut a sixth of a mile west of the upper falls, is mainly fine and coarse gravel, quite in contrast with the more common sand and clay. This difference in material is clearly explained, however, by a gap in the kame, which has been cut through and swept away by the river above the falls and on the north-west side of this terrace, which has been formed from it. Tributary streams have also often brought down coarse gravel deposits, forming deltas or contributing to the normal high terrace-plain, which on this account is often difficult to be precisely distinguished. Mascomy river, in Lebanon, and Little Sugar river, at North Charlestown, especially, have brought in these coarse deposits in large amount, changing the character of all the modified drift to a mile below their mouths.

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* The survey for this map was made when the river was above its ordinary height, which is at Hanover 373 and at White River Junction 333 feet above the sea.

† First edition, p. 548; second edition, p. 544.

A quarter of a mile south-west from White River Junction we find an ancient bed of White river, similar in position and height, and formed and deserted under the same causes with that of Pompanoosuc river (p. 37). This is a nearly level depression, 300 to 400 feet wide, 25 feet below the alluvial plain on the west, and 60 feet below the gravel ridge or kame on the east. Its height is 154 feet above the river on the north, or 487 feet above the sea. It descends only three feet in going 1,000 feet to the south, where the high plain in which it was formed, and the ridge which was its eastern barrier, have both been washed away.

Through Hartford and Hartland the upper terrace is well exhibited, of a normal height 525 to 500 feet above the sea, or nearly 200 feet above the river, and reaching one third to one mile back from it; but in several places this is broken by hills of ledge or till, isolated or extending across it nearly to the river. Its normal height is increased 40 to 80 feet by

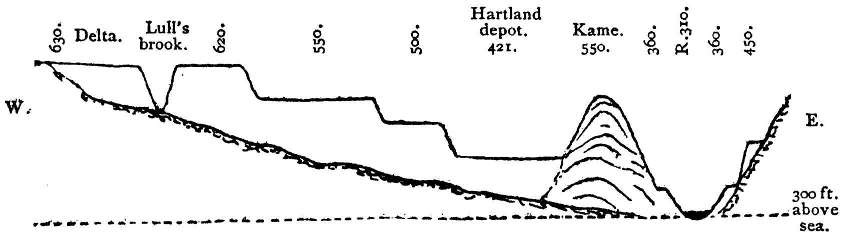
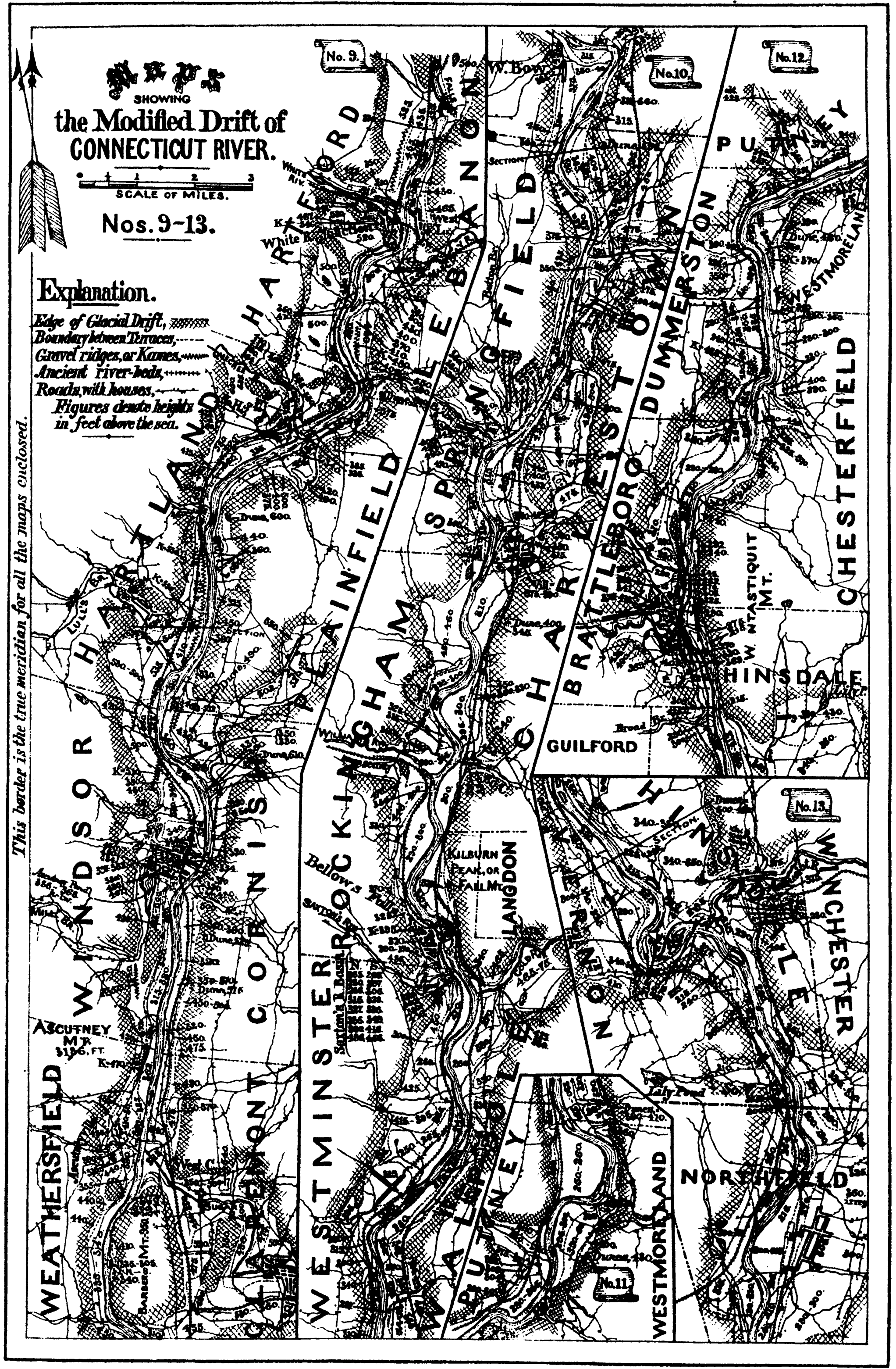


Fig. 10.—SECTION IN HARTLAND AND PLAINFIELD. Length, 1½ miles.

Plate III.



HELIOTYPE.

tributary alluvium for two miles south from Quechee river, and for one mile south from Lull's brook. A level-topped delta, on both sides of the latter at its opening into the main valley just south of Hartland village, is 320 feet above the river, which is less than a mile distant. This high delta is terminated by a steep slope of from 25 to 40 feet, below which, at the south, there is no line of separation between the additions from this brook and the ordinary highest terrace; but the whole shows an irregular surface of smoothly rounded hills and hollows, formed by small streams. Similar erosion has taken place west of North Hartland. This cause has frequently destroyed the true shape of these high plains, originally level, and bounded by a steep escarpment; instead of which we now find sloping buttresses, ravines, and scattered knolls and ridges, in a confusion quite opposite to the beautiful system and regular form of the terraces.

In Lebanon and Cornish steep hills of till or ledge come quite to the river at the lower descent of White River falls and opposite Windsor village; in Plainfield the hill comes near the river at Sumner's falls, and opposite Hartland village the alluvium is thus reduced to a very narrow strip for a mile. No very broad development of modified drift occurs in either of these towns. Of the original high plain we find only scanty remnants; the intermediate terraces are present, but as usual of small width; of the lowest terrace we have at the mouth of Mascomy river the largest expanse that occurs in the twenty-four miles along which the kame remains, but this comprises only about half a square mile, and it is mostly above the reach of high water.

The readiness with which the fine, loose modified drift may be channelled out by rivulets or springs is often shown by long, deep gullies extending from the edge of a terrace directly across some field, whose level surface was never before marked by any water-course or hollow. Such a gully, fifteen rods long, two to four rods wide, and fifty feet deep, has recently been made in a terrace 100 feet above the river, at a point two miles south of West Lebanon, on the east side of the river road, which was undermined and turned aside by it.

Dunes. Near the south line of Lebanon, east of Sumner's falls in Plainfield, and at several places in Cornish, we find banks of sand, or dunes, destitute of vegetation, and blown in drifts by the wind. These vary in height from a few feet to 100 feet above the highest terrace, from which they appear to have been carried up by the prevailing north-west winds. Southward they are found in many places on the east side of this valley, but none were seen in Vermont.

Deltas. A large amount of modified drift occurs on Blow-me-down brook. Three miles from its highest source, where the road crosses Croydon mountain, it has formed the plain of Cornish Flat, 855 feet above the sea, and six miles lower that of Plainfield village, 520 feet above the sea, with an older deposit 30 feet higher, at the north end of the village. Two miles farther down, where this stream opens into the broad valley, it has formed a delta of irregular slope from 512 to 420 feet. These tributary deposits often throw light on the history of the modified drift of the main river. We have seen that the deltas north of the continuous kame, as of Wait's river at Bradford, and Jacob's brook at Orford, were deposited before the completion of the original flood-plain of the Connecticut; but the deltas of Quechee river and Lull's brook appear to have been brought down at about the same time with this upper terrace, which is notably increased in height by them for a considerable distance; while the long sloping delta of Blow-me-down brook, covering a square mile and descending to nearly 100 feet below the normal highest plain, seems to be of a date subsequent to its formation and partial removal by the river. A conspicuous dune at the east side of this delta, derived from it and from the original high plain, is 610 feet above the sea, or 100 feet higher than the deposits from which it was blown.

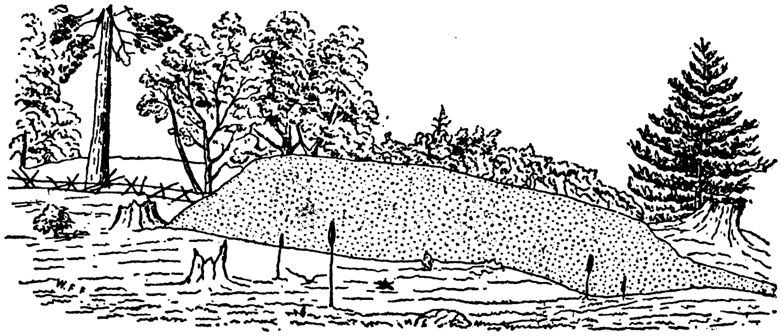


Fig. 11.—Sand Dune, near the South Line of Lebanon.

The Kame of Connecticut Valley.

From Lyme to Windsor we find a continuous gravel ridge or kame, extending twenty-four miles along the middle and lowest portion of this valley, with its top from 100 to 250 feet above the river, or from 500 to 600 feet above the sea. Its material is gravel and sand, in irregular, obliquely-bedded layers, always showing an inclined, and in most cases a distinctly anticlinal or arched, stratification. The sand is usually coarse and sharp, well suited for masons' use. It occurs in layers of varying thickness up to one or two feet, but sometimes it is wholly wanting. The gravel, which always forms the principal part of the ridge, varies in coarseness, from layers with pebbles only one or two inches in diameter, to portions where the largest measure one and a half or two feet. The finer kinds prevail; and the channels of brooks cutting through the ridge frequently show no pebbles exceeding one foot in size. All the materials of this kame, and of its remnants along this valley, are plainly water-worn and stratified.

Large and unworn boulders, which could not have been brought in the same way with the gravel and sand, occur very rarely upon or in the Connecticut kame. Except at its south termination, the only instance of this discovered was three fourths of a mile south of Pompanoosuc river, at the point where the kame reaches its greatest height above the sea. Two angular boulders, each of five feet dimension, were found here at the top of the ridge, one lying on the surface, and the other partly imbedded. This place was covered with a thick growth of sapling white pines. Several miles at least of journey on foot along the top of this ridge, and the examination of many sections where the river or its tributaries have cut through it, failed to reveal other boulders of this kind.

One or both sides of this kame are generally covered by the alluvium of the upper terrace, which plainly was of later deposition; but the top usually projects in a long, rounded ridge, 10 to 30 feet above the adjoining highest plain. At one place, east of Hartland depot, this plain has been swept away from both sides, and the kame forms a conspicuous, steep ridge 125 feet in height. Wherever it is exposed, it is readily recognized by the pebbles which strew its surface, and which are very rarely found in the ordinary modified drift of the valley.

The most important feature of this kame, if we compare it with others in New Hampshire, is, that along its entire extent it constitutes a single continuous ridge, which runs by a very direct course nearly in the middle of the valley, having no outlying spurs, branches, parallel ridges, or scattered hillocks of the same material associated with it. The kames in the Merrimack valley and in eastern New Hampshire also average much coarser, and more frequently contain angular boulders, while in some places they show a gradual transition from sand and water-worn gravel to unmodified moraines.

This remarkable ridge shows the course of the glacial river by which the floods from the melting ice, laden with gravel, sand, and clay, found their way between ice-walls to the open valley below. All the material which was thus brought down was probably gathered from the melting surface of the ice-sheet; and the pebbles were rounded in being carried along by its streams. Near the mouth of the channel in which these waters flowed, a portion of their gravel and sand was deposited with the alternation of summer and winter. Elsewhere, kames may have been formed by rivers beneath the ice-sheet; and when many boulders are contained in them, or found on their surface, they seem to be most readily explained by supposing them dropped from a melting roof of ice. It is at least plain, that if any kames have been formed under the ice, they must contain many boulders derived from this source. In nearly all the kames of New Hampshire it seems more probable that the angular materials and large boulders, which we find associated with these water-worn deposits, were brought by the same currents, frequently in floating masses of ice. Their infrequency here puts it beyond doubt that the kame of Connecticut valley was formed in an open ice-channel. It is probable that this did not extend at one time over the whole distance where we find the kame, but that it was gradually formed as the melting advanced northward, which was at so slow a pace that for a long time walls of ice enclosed the deposits of the glacial river. After these walls melted, the gravel and sand remained in a long, high ridge, which became nearly covered by the subsequent slow deposition of the high alluvial plain.

When the river entered upon the work of excavating its present channel in the alluvium, the kame was a barrier which confined erosion to the area on one of its sides and protected its opposite side; so that this ridge of gravel often forms the escarpment of a high plain, with the river flowing at its base. On this account we find the upper terrace occupying a greater width along the course of the kame than it averages elsewhere in this valley.

In calling this kame continuous from Lyme to Windsor, it is not meant to imply that it is now entire, since it has been frequently cut through and considerable portions swept away by the main river and by tributary streams; but that so much of it remains as to make it certain that it originally formed an unbroken ridge. The portions now separated by gaps always lie in a continuous line.

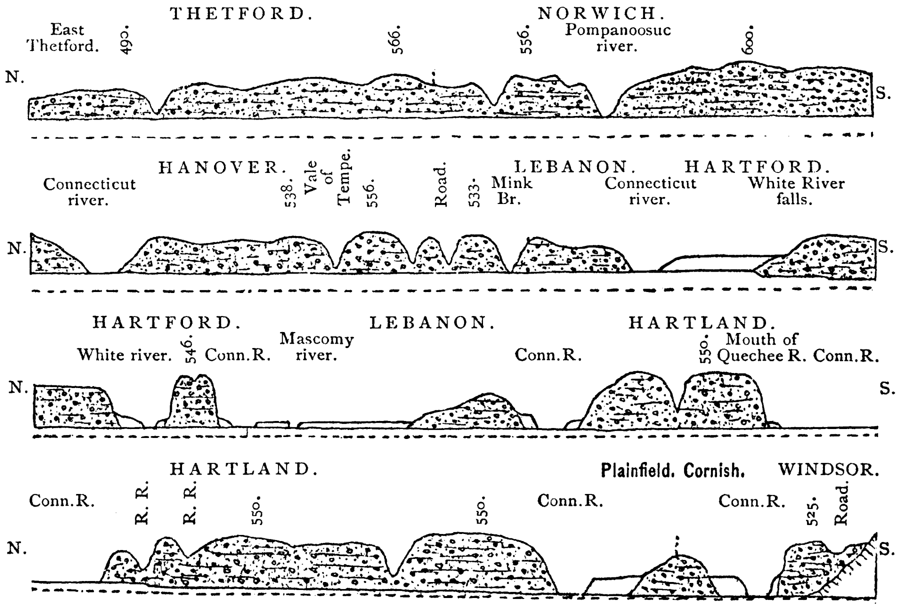


Fig. 12.—PROFILE OF THE KAME OF CONNECTICUT VALLEY (24 miles; vertical scale, 1 inch=800 feet).

The dotted line marks a height 300 feet above the sea, and the line next above represents the river.

The first evidence that we find of this ridge is a coarse gravel deposit on the south side of a hill in Lyme, one mile north of the mouth of Grant's brook. For about one mile south from this point it has been carried away by the river. It then commences about one third of a mile south-west of the railroad station in Thetford, and thence extends southward with the profile shown in Fig. 12. It is nearly straight four miles to the mouth of Pompanoosuc river, which has cut through it, but was at first turned south by it, as shown by an ancient river-bed (p. 37). There is a slight bend in the kame at this point, but it continues with very nearly the same course eleven and a half miles farther to the south line of Lebanon, where it bends with the valley. It has no long gaps in the first half of this distance above White River falls. The Connecticut has formed for itself a more irregular course than this of the old glacial river, first flowing with the kame at a considerable but varying distance on its west side; then, about two miles south of Pompanoosuc river, it cuts through this ridge, which thence through Hanover and Lebanon forms its high east bank to these falls. Gaps have been made in Hanover at the Vale of Tempe, at Webster's vale, at the road to the bridge, and by Mink brook. The second and third places are outlets of long gullies, which now have no running streams.

At White River falls one mile of the kame has been removed by the river, giving coarse materials for terraces below (p. 40). It appears next in Hartford, where it is cut through by White river, south of which a good section of it is shown only a stone's throw from the Junction depot. Next, about a mile and a half has been swept away by the Connecticut, across the area now occupied by the low terrace at the mouth of Mascomy river. A remnant is found in the south part of Lebanon, but it is soon crossed again by the river, and then continues a mile on the west side from the north line of Hartland to the mouth of the Quechee river. From this point, for two miles to Sumner's falls, it has been washed away by the Connecticut, which probably occupies nearly the former place of the kame. Thence it forms a high ridge close upon the west side of the river for nearly three miles to the mouth of Lull's brook. Next a remnant appears on the east side, at the line between Plainfield and Cornish, south of which it is cut through by the Connecticut for the seventh and last time. A section of it is exposed here on the south-west side of the river and railroad, where the largest pebbles seen were a foot in diameter. Thence it is well shown for a third of a mile south, reaching somewhat above the highest terrace, but with a natural gap 40 feet below its general level where it is crossed by the road. It terminates a short distance farther south-west, resting upon the side of a ledgy hill, about one mile north-west from Windsor village. The portion south of the road has a few boulders on its surface, which takes the form of a terrace.

Probably a similar gravel ridge once existed along the valley southward, though now shown by only a few fragments; and it seems proper to add here whatever facts we have on this subject. Gravel, which is unmistakably that of the kame, was seen in the west part of Windsor village, exposed by excavation at a street corner some 500 to 600 feet north-west from the dam of Ascutney pond. Here all of the kame that was above the street has suffered erosion, and all else seen was fine alluvium. On the east side of Ascutney pond we find a high, nearly level-topped area of kame-like gravel. This extends from north to south about three fourths of a mile, being one eighth of a mile wide, with a steep escarpment on each side. This seems to be a kame deposit, wider than usual, and resembling the high plains or broad ridges of the same origin about Dover and southward near the coast. The south end of this deposit rests upon the north end of a ledgy hill. A mile and a half farther south we find distinct remains of the kame close upon the west side of the river road, extending about one mile with equal portions in Windsor and Weathersfield. This forms the east border of a high terrace, both kame and terrace being 150 to 170 feet above the river. The material of this kame is plainly shown by excavations made for repair of the road, and it is like that which uniformly prevails in the long range from Lyme to Windsor. Thus we find frequent gravel deposits which are probably remnants of a former kame along the first five miles south from the end of the undoubtedly continuous range. It is noticeable that here the kame was near the west side of the valley, with its continuity broken by hills.

In the next eleven miles no indications of the kame were seen. It is then quite well shown for one mile in Charlestown, first appearing where the railroad cuts the high terrace south of Beaver meadow. This exposes a section of the underlying kame, and between Springfield station and the Cheshire bridge it forms a gravel hill, with a height in both places 130 feet above the river, or 420 feet above the sea. Eight miles intervene before we find its next remnant, which is a pine-covered plateau, used as a picnic ground, in the north part of Bellows Falls village. This is 75 feet above the streets that surround it, 112 feet above the river at the head of the falls, and 395 feet above the sea. At its north end a section is exposed, which shows this to be a portion of a kame by its material, which is the characteristic coarse gravel, and by its anticlinal stratification. The next fifteen miles afforded no evidence of the kame. We then find three remnants of it in six miles, and below these nothing in the following fifteen miles, or to the end of our journey, which extended through Northfield, Mass. The first of these remnants was near the south-west corner of Westmoreland, 158 feet above the river and 370 feet above the sea. The second was a short distance south-west from Dummerston station, 215 feet above the river and 425 above the sea. The river has swept this away at its south end, and the railroad is here built across its terminal slope, which shows a fine anticlinal stratification. The most southern portion of the kame found remaining in this valley is at the north side of West river, lying on ledges between the railroad and the highway, where we have a well-defined gravel ridge 160 feet above the river and 360 feet above the sea.

These peculiar deposits, similar in material and stratification with the kame that extends from Lyme to Windsor, were plainly once more extensive than now, and probably are portions of an originally continuous ridge. Long gaps have been washed away in the southern half of the range, from Lyme to Windsor; and farther south the river has left only scanty remnants of this oldest modified drift of its valley.

Returning now to the later deposits, which have been shaped by the river into terraces, we will begin where we left them, at Cornish and Windsor. The original highest flood-plain of the river in these towns and through Claremont and Weathersfield seems to have sloped from 500 to 450 feet above the sea. The river from Windsor to Bellows Falls, 26 miles, has a very gentle descent from 304 to 283 feet above the sea. Hence it will be sufficient in this distance to state only heights above the sea, from which that above the river may be easily determined.

The terraces of Windsor village are very interesting. That at the depot and railroad is 330 feet above the sea; of the post-office, 354; of the street leading west past the state prison, 382 to 397, rising 15 feet in going a half mile away from the river. The last remains now in the form of an isthmus, having been channelled out by the river on the north side of this street to a depth of 60 feet, and to the same amount on the south side by Mill brook. The highest terrace, increased by a tributary, is shown farther west.

The railroad in Cornish and to within one mile of West Claremont, or for a distance of four miles, is built on one continuous terrace, from one sixth to one third of a mile wide, and sloping in this width some twenty feet towards the river. The west side of this terrace has a height of from 360 to 350 feet. A terrace of corresponding height extends nearly the whole distance opposite to this on the Vermont side. A narrow belt of interval is found much of the way between these terraces and the river, but for the last mile, at the north corners of Claremont and Weathersfield, they are separated only by the channel. These are plainly the remains of a former flood-plain, intermediate between those of the Champlain period and of the present time.

Several hills of ledge and till, entirely surrounded by modified drift, occur in this part of the valley. One of these, in Windsor, turns Mill brook north into Ascutney pond. Another occurs in Weathersfield, about one mile south of Ascutneyville. The largest of them is Barber's mountain in Claremont, which occupies an area more than two miles long by one mile wide, and reaches an altitude of 950 feet above the sea. This has smooth slopes of till on the north and east, but presents abrupt ledges on the west and south. It stands directly in the line of the river's course, so that as it is approached it seems at first to form a barrier across the valley. The Connecticut has always flowed by its present detour on the west side of this mountain. At its north end a remnant of the original high flood-plain is preserved, being 440 feet above the sea; and in Vermont this upper terrace is well shown for half a mile farther south. It is then wanting on the west side of the mountain and for more than a mile in Vermont, but reäppears at its south end on both sides of the river, being continuous on the west side to the north line of Springfield. Scarcely any alluvium remains at the west foot of the mountain. A very narrow strip, however, extends for a mile along the river's edge, notable for its slope of twenty feet in this distance from 325 to 305 feet above the sea. The opposite terrace in Weathersfield, about 340 feet in height, extends more than two miles, with a nearly uniform width of one sixth of a mile, west of which rises a high steep hill.

The high alluvium on the east side of Barber's mountain is the product of Sugar river, and while it was being deposited the Connecticut flowed in its present course. This is shown by the height and configuration of its surface, which tell its origin and mode of deposit. The railroad passes by this route, and the portion in which we are interested is from Sugar river to Claremont junction. East of the railroad Trisback hill rises 850 feet above the sea. This obstacle turns back the course of Sugar river at a sharp angle, whence it flows by a long bend on the north side of the hill. The channel of Sugar river is cut 150 feet deep in its original plain, over which its highest floods at the end of glacial time poured into the Connecticut valley by two routes, one as now north of Trisback hill and Barber's mountain, the other south of these towards Ashley's ferry. The highest portion of this plain in Claremont village is 565 feet above the sea, or 40 feet higher than the river above the upper dam. It thence slopes to 530 feet at one third of a mile east of the junction, and is shown on the east and north sides of the river to West Claremont, sloping to 540 feet. The deposits of modified drift which are cut by the railroad at Ellis's bridge, a mile south of Sugar river, and again just north of the junction, being respectively 515 and 500 feet above the sea, are remnants of these plains. They were both brought down at this time by the floods of Sugar river, the former on the north side, the latter on the south side of Trisback hill. The space between these deposits is a swamp, from 30 to 40 feet lower, showing that the supply was not sufficient for filling the whole area west of this hill.

The descent of Sugar river at Claremont village is 125 feet, of which about 100 feet is used for water-power. Below the foot of these falls it descends 100 feet more before it joins the Connecticut at 300 feet above the sea.

In Charlestown and Springfield the normal high flood-plain of Connecticut river was probably about 450 feet above the sea, or 150 above the river; but it is here more obscured by higher tributary deposits and the terracing process of erosion than in any other portion of the valley. It appears to be shown in the broad, uneven terrace west of Calavant hill; probably in that over which the railroad passes south from North Charlestown station; in the first terrace east and south from Beaver meadow, but not in that of the fair-ground and road northward, which is the delta of Beaver brook; in the terrace east of the cemetery at the village of Charlestown; and in the highest terrace, two miles long, above South Charlestown.

An interesting dune was noted on the north-west slope of Calavant hill, near the north line of Charlestown. Its height is 598 feet above the sea, or about 150 feet above the original plain from which it was blown by the north-west winds, as indicated by the sand-drifts, now principally covered by grass, that were left in its path.

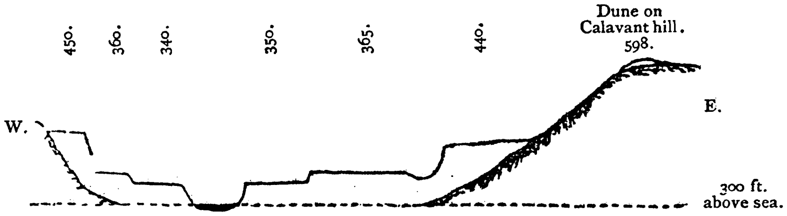


Fig. 13.—Section in Springfield and Charlestown near their north lines. Length, 1¼ miles.

South from Little Sugar river a high terrace of till, on which the road is built, extends a mile and a half to the east side of Rattlesnake hill. It is nearly level-topped, and of about the same height in its whole length, being 550 feet, sloping to 540 feet above the sea. This terrace is composed of till, apparently unstratified and scarcely modified, except so far as its terraced form may be due to water. This is the upper till, distinguished by its comparatively loose and sandy character. The underlying member is exposed by the gully of a brook near the school-house, being a blue, very compact, stony clay.

In Springfield the whole or a part of the modified drift, lying between 320 and 350 feet above the sea, presents an irregularly sloping contour for four miles, from the north line of the town nearly to Skitchawaug mountain.

In Rockingham, opposite the south part of Charlestown, we find two considerable areas, which appear to be remnants of the river's highest plain. One of these, more than a mile long by two thirds of a mile wide, is in the north part of the town, bordering the river. The second is as long, but only one fourth mile wide, extending to the south from near the mouth of Williams river.

Deltas. Three prominent deltas occur in these towns, the products of Little Sugar, Black, and Williams rivers, with heights respectively 530, 520, and 500 feet above the sea. The greatest extent of these deposits now remaining is in each case on the north side of the stream. Only the upper portion of the delta of Little Sugar river is of the height mentioned. Its principal mass is 50 feet lower, being the terrace cut by the railroad one third mile north of the river. It is almost wholly composed of gravel, in which the largest pebbles are one foot in diameter. In the midst of this gravel a stratum 1½ to 3 feet thick, consisting of clay in layers a third of an inch thick, interstratified with a clayey sand, was exposed for 75 feet on the west side of this cut. Along half this distance it was levelly stratified, but beyond was irregularly crumpled, as shown in Fig. 14, apparently by lateral pressure.

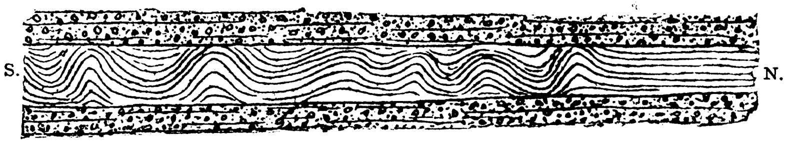


Fig. 14.—Folded Clayey Layer in horizontally stratified Gravel, North Charlestown. Scale, 1 inch=10 feet.

The wide, high delta of Black river has been cut through by Button brook, and has been variously terraced both by this brook and by Black river. A considerable portion of its plain between these streams is covered by heavy white pine woods. This delta increases the height of the upper terrace for more than two miles southward. The delta of Williams river is less extensive than the preceding, and at the same time has less thickness, as it has been partly protected from erosion by ledges, which in some places form its border.

Two miles north from Williams river the west bank of the Connecticut exhibits an interesting section (Fig. 15) of synclinal strata of clay and sand eroded to a level top, and overlaid by levelly stratified sand. The synclinal deposit appears to be the lower part of that which once filled the valley. After its upper portion had been carried away, the overlying sand was brought in by a tributary, and subsequently terraced by the river. The most noticeable feature of the modified drift north and south from here is the wide interval or meadow, which extends from Charlestown village to Bellows Falls, and lies partly on each side, being several times crossed by the river.

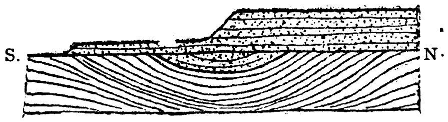


Fig. 15.—Section of River-Bank, Rockingham, Vt. Scale 1 inch=100 feet.

From South Charlestown to Cold river the precipitous face of Kilburn peak or Fall mountain forms the eastern boundary of the modified drift. Opposite Bellows Falls this leaves scarcely room for the railroad and the highway between it and the river. The height of this mountain is about 1,200 feet above the sea. The water-shed on its north-east side in Langdon, between the brook which flows into the Connecticut at South Charlestown and one of the branches of Cold river, is a swamp one sixth of a mile wide, 458 feet above the sea, or 175 feet above the river. Modified drift, mainly coarse, extends south from this water-shed to Cold river. It was formerly supposed that the modified drift was deposited at a time when the valleys were made a series of lakes by the existence of barriers since swept away, and the narrowest space at Bellows Falls was regarded as the probable site of such an obstruction. No evidence pointing to this was seen by us here or in any other portion of the valley, except so far as deltas, the ridge of the kame, or other unusually high deposits of modified drift may have acted in this way for a short time. It is obvious that with any high barrier here the river would have found passage over the low water-shed north-east of the mountain.

At Bellows Falls the river descends 49 feet (from 283 to 234 feet above the sea), through a narrow, water-worn channel of rock. Distinct glacial striæ are seen upon these ledges at the head of the falls. The original highest plain seems to be shown by the upper terrace, 425 feet above the sea, which extends one mile north from the falls on the east side. This is about 30 feet higher than the remnant of the kame (p. 47), around which the high plain has been wholly swept away and the principal terrace of the village formed, from 325 to 320 feet above the sea. This area of fine alluvium extends a third of a mile west from the falls, and it is almost certain that somewhere beneath it is a rocky channel lower than the head of the falls, in which the river flowed before the glacial period. In excavating the modified drift which was afterwards deposited, the river has formed its present channel close upon the east side of its valley, passing over ledges which are probably much higher than its preglacial bed.

Cold and Saxton's rivers have brought down large amounts of modified drift 75 feet above the normal high plain. The proper delta of the former has been eroded so far as it occupied the main valley, but the escarpments thus formed remain at the mouth of the valley of Cold river, from 100 to 200 feet high. Thence a wide plain is found on the south side of Cold river for one mile, and again one half mile farther east at Drewsville. The west part of this deposit is sand or fine gravel, but in the east portion coarse gravel prevails.

On the south side of Saxton's river a considerable part of its delta remains, and the upper terrace is increased in height by this cause for two miles south. The excavation of this delta by Saxton's river has formed a most interestingly terraced basin, situated less than a mile south from Bellows Falls junction. On both sides of this river, and crossed by a road, is an interval about one fourth of a mile in diameter. Around this on all sides are ranged terraces, which rise in succession like the seats of an amphitheatre, the highest on the north-west being 220, and on the south 200 feet above the arena below. They do not, however, show a perfect regularity either in correspondence of height or in continuous extent, and no single section would embrace all of the eight distinct and separate terraces which we noted on each side of the river.

At Walpole village the limits between alluvium and till are not so distinct as usual. The highest terrace of the Connecticut appears to be shown here 395 feet above the sea, and it is nearly continuous southward through this town, descending to 360 feet at its south line, where numerous dunes occur 30 to 50 feet higher. Irregular terraces intervene between this highest level and the river.

In Westminster, opposite Walpole village and for one or two miles north and south, the modified drift is wide, and lies in beautiful, broad terraces. That of the village is 90 feet above the river, or 315 above the sea; another, 50 feet lower, extends one mile northward to the bridge.

Through Westmoreland and Chesterfield the upper terrace varies between 400 and 350 feet above the sea, the former height being reached by deltas three fourths of a mile south-west from Westmoreland depot and at and below the mouth of Catsbane brook. The modified drift in these towns is generally very narrow; but bends in the river give it a width of two thirds of a mile at two places in Westmoreland, one of which is a mile and a half south-west from the depot, and the other the same distance north from the south line of the town. At both these points dunes occur on the hillsides just above the terraces.

In Putney, Dummerston, and Brattleborough, opposite the foregoing, we find nearly the same normal limit of the modified drift, and increased height of that brought in by tributaries. A bend of the river at the north-east corner of Putney gives to that town a notable expanse of low terrace, covering three fourths of a square mile. Many of the terraces in Dummerston, especially for two miles north from the depot, slope more than is common towards the river, and are less distinctly separated by the usual steep escarpment. An interesting remnant of the kame occurs a third of a mile south-west from the depot (p. 48). At the west side of this ridge is a hollow of 100 feet, beyond which is an extensive deposit of kame-like gravel, which has been protected from erosion by a border of ledges on its south-east side. This has about the same height with the top of the kame, and appears to be of similar origin.

Two large streams—West river and Whetstone brook—join the Connecticut in Brattleborough. The latter flows through the centre of the village, supplying valuable water-power. A large part of its delta remains in the high plain at the south and south-west. The height of this a mile west of the river is 425 feet above the sea; at the Catholic cemetery, 409; at the fair-ground, about 400. Above the west part of this plain, however, a still higher delta, at 490 feet, has been formed by a small tributary of this brook. This is the highest deposit of modified drift found in this valley south of Bellows Falls. The height of Connecticut river here is 200 feet above the sea. In the north-west part of Brattleborough village there rises a ledgy hill, about 525 feet above the sea, below which on the west is a belt of alluvium, extending north from the delta of Whetstone brook to the valley of West river. Its northward slope shows it to be a part of the delta deposit of this brook. In the village erosion has removed the delta, giving on the north three principal terraces, 290, 308, and 341, and on the south two, 300 and 369, feet above the sea.

West river is situated one mile farther north, and is larger than Whetstone brook; but it is of less interest, because it forms an exception to a general rule, having apparently brought no delta into the Connecticut valley. It has, however, labored so abundantly in hollowing out its channel, that its course is through a beautiful basin, somewhat like that on Saxton's river, mainly overflowed at high water and bordered by terraces. On the north side of its mouth are the most southern remnants of the kame (p. 48); and on the south side an interesting series of secondary terraces, left as bench-marks of its progress in excavating the basin.

The view of New Hampshire from Brattleborough is similar to that from Bellows Falls. At both these places, the largest towns in Vermont on this river, its eastern shore is an abrupt mountain wall, against which no terraces or only scanty remnants are found. Wantastiquit or West River mountain extends nearly four miles, with about equal portions in Chesterfield and Hinsdale, and rises to an altitude about 1,200 feet above the sea. The lowest point of water-shed at the east, near the head of Catsbane brook, is by estimate 650 feet above the sea, or about 200 feet above the highest portion of the Hinsdale plain.

South-east and south from this mountain is the most extensive plain on this river in New Hampshire or Vermont, being three miles long, with a width decreasing from two miles to two thirds of a mile. The road from Hinsdale to Brattleborough passes over the south end of this plain. Here its height is 350 feet above the sea, or 165 above the Connecticut at the mouth of Ashuelot river. It is mainly composed of sand, nearly level, but with a slight slope to the west and south, being as usual towards the river and in the direction of its course. Its extremity, three fourths of a mile south-west from this road, is twenty feet lower. Northward, its west edge is about 340 and its east side probably as high as 380 feet above the sea. Its northern portion changes to gravel, which becomes coarse on the south-east side of Wantastiquit, containing pebbles one foot or sometimes a foot and a half in diameter. The position and slope of this plain show that it was not deposited wholly from currents of the main valley; evidently a considerable portion was contributed from the melting of the ice-sheet east of Wantastiquit mountain.

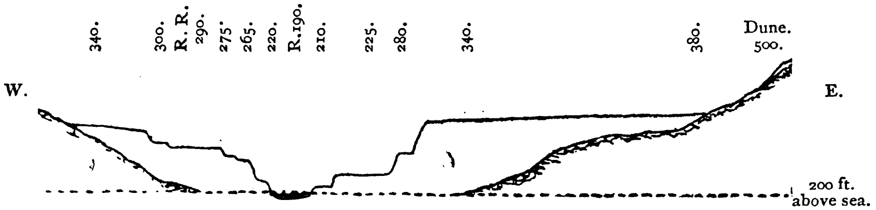


Fig. 16.—SECTION IN VERNON AND HINSDALE. Length, 3 miles.

Extensive sand-drifts or dunes blown from this plain occur on the hills at its east side for a mile and a half north from Hinsdale village. The highest of these at present drifted by the wind are about 100 feet above the east edge of the plain, but large amounts of sand now grassed over extend 50 feet higher.

Ashuelot river at Hinsdale, and for a mile east, is bordered by terraces but little higher than the plain. Slight remains of an older delta, about 400 feet above the sea, appear at its opening into the main valley, especially above the railroad east of its mouth. This stream, like Whetstone brook at Brattleboro', has formed numerous and interesting terraces in the alluvium of the Connecticut during the excavation of its channel to join that river.

In Vernon, a high delta of small extent occurs on the north side of Broad brook. An isolated plateau, 70 feet above the low terrace surrounding it, and plainly a remnant of the principal terraces north and south of this brook, is found on its south side close to the river. It has been cut through for the railroad. Another plateau, similar to this, but only 15 feet in height, is cut through by the Ashuelot Railroad, just north of South Vernon. For two miles north from Vernon village the modified drift averages one mile wide, and is very finely terraced; a half mile west from this village it consists of an extensive delta, 410 feet above the sea. One of the most picturesque portions of this river, as seen in our boat journey, was at this place in the circuit around Cooper's point, where the river is divided by islands, and frequent gneissic ledges are exposed along its shore. These islands, and others along the river, are in nearly all cases alluvial and within the reach of high water. For a half mile east from Vernon the current of the river, by reason of this bend, has been so directed against its south shore that scarcely any alluvium remains, instead of which we have an irregular slope of till and ledge.

Opposite Northfield village we find a prominent delta-plain of gravel, 390 to 375 feet above the sea; and the first brook north of this village has brought down kame-like gravel and irregular delta deposits of similar height. The normal highest plain of the Connecticut seems to be represented by the west portion of the Hinsdale plain; by the irregularly sloping terrace, which extends two miles north from Vernon, with its upper edge 340 feet above the sea; by an extensive terrace one mile east of Vernon, at 330; probably by terraces north and south of South Vernon, at 295 and 290; by irregular remains in the south part of Hinsdale, at 350, expanding into a plain in the south-west corner of Winchester, with a slope from 325 to 310; and by the plains at and south from Northfield village, about 300 feet above the sea, or 120 feet above the river.

An examination of the southern maps of Connecticut river (p. 40) shows a second apparently connected series of terraces, which probably marks one of the principal flood-plains formed by the river during its work of erosion. It exhibits a similar slope with that of the highest plain, or of the present river with its bordering intervals. This series is most clearly continuous below the north line of Brattleboro', but seems to be traceable from White River falls, where it appears in the terrace on the west, from 435 to 455 feet above the sea, formed from the undermined kame. It occurs north and south from West Lebanon, at 430 and 440; one mile south of Mascomy river, at 440; opposite to this, at from 430 to 410; at North Hartland and opposite, from 412 to 400; probably at Hartland depot, from 425 to 410; in the north-west corner of Cornish, from 380 to 375; at Windsor post-office, 354; in the terrace of the railroad for four miles southward, from 360 to 350; in the principal terrace opposite Barber's mountain, from 340 to 335; east of Weathersfield Bow, from 350 to 340; in the north part of Charlestown and Springfield, small terraces, 350; south from Black river, 360; on the road from Cheshire bridge to Charlestown, 350; in several places to South Charlestown, from 345 to 340; in the narrow curved terrace on which the road runs, one to two miles north of Williams river, from 335 to 330; in the principal terrace of Bellows Falls, and that of the Sullivan county railroad for one mile north, from 325 to 320; between Cold river and Walpole, 330; along the railroad, one to two miles south from Walpole, from 315 to 308; at Westminster village, 315; in scanty terraces, for five miles south, from 315 to 300; at East Putney and opposite, from 300 to 280; for eight miles southward, numerous terraces, sometimes irregularly sloping, from 310 to 290; in Brattleboro', from the north line to West river, a broad level terrace, 290; in the village, 290 and 300; at the mouth of Broad brook, the same; in the wide terrace of the railroad north from Vernon, 290; probably at Cooper's point, 274; opposite Ashuelot river, 275; at South Vernon, 270; on the west side of the river in Northfield, from 264 to 260; and on the east in a continuous terrace, varying from 270 to 260, extending from one mile south of Hinsdale to the limit of our map and survey, two miles south of Northfield village.

It will be seen that this list embraces the most conspicuous terraces below the highest plains. The formation of the terraces has taken place by excavation of a vast deposit that filled the valley level with these upper plains; and it might happen that at some period in the deepening of the channel the river would hold nearly the same height for a longer time than usual, after which the deepening might go on rapidly again, leaving the broad flood-plain then formed to be shown only by remnants, as in this series. At the least, it cannot be doubted that this is the true explanation of its most notable portions, as for the eighteen miles through Brattleboro' and southward, and for eight miles south from Windsor.

Recapitulation of Modified Drift of Connecticut River.

PLACES.	Distances in miles from Conn. lake.		HEIGHTS IN FEET ABOVE THE SEA.			
	Direct course (valley).	Course by the river.	Connecticut river.	Highest normal terrace.	Highest tributary deltas.	Altitudes for reference, and remarks.
Labrador brook, . . .	5.4	5.6	About 1300	Above the river. 5		Fourth lake, 2551. Third lake, 2038.
Deadwater stream, . .	7.5	8		10, S.		Second lake, 1882. Connecticut lake, 1618.
Outlet of Back lake, .	8	8.5		10, N.	Above river. 30	Red school-house at the "Hollow," 6 miles from Connecticut lake, 1495.
Indian stream, . . .	10.8	11.4		15, N.	30	Hall's Stream bridge, 1098.
1 mile to south-west, .	11.8	12.4		40, W.		W. Stewartstown bridge, 1053. " dam, 1049.
Bishop's brook, . . .	14.3	15.2		15		Colebrook bridge, 1025. Columbia bridge, 1011.
Hall's stream, . . .	15.2	16.3	1085	1120, N.	1120	North Stratford station, 915. Beattie's (flag) station, 880.
West Stewartstown and Canaan, ...	17.5	18.7	1049–1035	1100, W.	Leach str., 1100	Stratford Hollow, 877. Groveton junction, 901.
2 miles south, ...	19.5	21	1025	1080		Hay scales, Northumberland Falls, 865.
4 "	21.5	24	1017	1060		Lancaster court-house, 867. " station, 862.
Colebrook, ...	24.5	27.5	1010	1050	Beaver br. and Mohawk river, 1100.	Sumner house, Dalton, 898. Upper Waterford bridge, 689.
Columbia bridge, . .	28.3	31.7	992	1040, W.	Sims str., 1090	" " hay scales, 752.
Rapids 7 miles below Beaver brook, . . .	30–37	33.5–41	990–891	50–60 ab. riv'r		Railroad near the mouth of Passumpsic river, opposite high wooded island, 490.
North Stratford and Bloomfield, ...	37	41	891	1010, E.		Barnet station, 467. Stevens River dam, 557. Barnet church, 602.
1½ miles south, . . .	38.5	42.6	880	980 W.		McIndoe's station, 488. " church, 510.
3 " . . .	40	44.2	875	965, E. 950, W.	1000 W.	Monroe store and P. O., 540. Ryegate station, 471.
5 " . . .	42	46.5	868	950, E. 930, W.		Wells River station, 443. Railroad bridge, Connecticut river, 455.
6 " . . .	43	47.8	865	940, E. 930, W.		Woodsville station, 455. School-house, 1 mile S. E., 526.
Stratford Hollow, . .	45	51.5	858	935, E.		North Haverhill church, 506. " " station, 508.
1½ miles south, . . .	46.5	54.2	856	920		Haverhill town-house, 754. J. N. Morse's house, ½ mile south, 899.
Groveton, ...	49	58.5	854	900		Newbury station, 426.

PLACES.	Distances in miles from Conn. lake.		HEIGHTS IN FEET ABOVE THE SEA.		
	Direct course (valley).	Course by the river.	Connecticut river.	Highest normal terrace.	Highest tributary deltas.
Northumberland Falls and Guildhall, . .	51	62	852–842	900, W.	
1½ miles west, . . .	52.5	63.5	840	865, E. 900, W.	Gaskill br., 940
3 miles north of Lancaster, ...	53.5	65.5	838	865, E. 870, W.	
Lancaster, ...	56.5	70	835	865	Israel's riv., 910
South Lancaster and Lunenburg, ...	60.7	76.2	832	860	
Mouth of John's river,	63.2	79	830	850	John's riv., 870
First half of Fifteen-miles falls, ...	63.3–74.3	79.1–90.5	830–674	Above the river, 40–60	Ab. r. Niles st., 70
Upper Waterford, . .	74.3	90.5	674	50–60	N. & S., 100
Lower Waterford, . .	77.3	93.5	643	50–200?	
Fifteen-miles falls, below Lower Waterford,	77.3–82.3	93.5–98.8	643–465	150–200	
Passumpsic river, . .	83.5	100	460	650	
Barnet, ...	85.4	102	452	600–618	Stevens riv., 675
Monroe and McIndoe's falls, ...	87.6	104.9	440–430	588, E. 580, W.	
1½ miles south. . . .	89.1	106.5	427	575, E. 569, W.	
4 " . . .	91.6	109.2	420	555, E. 535, W.	
Woodsville and Wells River, ...	95.4	113.7	407	520–530	L. Am. river, 632, N.; 628, S. Wells river. 600–660.
North Haverhill and Newbury, ...	100	120.5	398	505, E. 478, W.	505–752, E.
Haverhill and So. Newbury, ...	103.3	125.2	392	475, E. 469, W.	Oliverian br., 630–750.
Bradford, ...	107.5	130.8	389	469–465	Wait's river, 583–600.
Piermont, ...	109.5	133.8	387	460, E. 465, W.	East. brook, 500–650.
1½ miles north from the mouth of Jacob's br.,	111.8	137	384	440	Jacob's br., 530 E.; 575, W.
Orford and Fairlee, . .	113.8	139	383	435, E. 440, W.	Jacob's brook, 560–690.
Ely station, ...	116.2	141.8	381	443, E. 435, W.	530, W.
North Thetford, . . .	118.4	144.5	379	525 W.	
Lyme and East Thetford, ...	120 3	146.5	378	525–545	Grant's brook, 535–635.
North line of Hanover and Norwich, . . .	123.6	150	376	535	
Pompanoosuc river, . .	125.2	151.6	375	545–552	590
Hanover and Norwich,	129.8	156.5	373	500–545	Mink br., 586; 564. Bloody br., 585; and 555–525.
West Lebanon & White River Junction, . .	133.8	160.6	333	510, W.	Mascomy r., 550.
North Hartland, . . .	138.3	165.6	323	500	Quechee river, 550–650.

Altitudes for reference, and remarks.

Haverhill sta., C. & P. R., 412.
" court-house, 664.
Bradford station, 410.
Piermont station, 439.
" M. E. church, 596.
Shaw's mountain, about 750.
Water station of railroad near Sawyer's mountain, 449.
Fairlee station, 438.
Orford bridge, 410.
" street, 422.
Morey mountain, about 900.
Fairlee pond, 415–419.
Ely station, 433.
North Thetford station, 402.
East Thetford station, 413.
Childs pond, 520.
Lyme church, 558.
Post pond, 430.
Water-shed between do. and Grant's brook, 545.
R. R. bridge, Pomp. river, 409.
Norwich station, 406.
" church, 530.
Hanover, College church, 552.
White River Junction, 369.
R.R. bridge, Quechee riv., 370.
North Hartland station, 388.
Railroad summit, 1½ miles north of Hartland, 464.
Hartland station, 421.
B. F. Labaree's house, Hartland village, 620.
Plainfield village, 520.
Windsor station, 331.
Railroad bridge, Connecticut river, 352.
Vermont state prison, 389.
Ascutney Pond dam, 386.
Balloch's crossing, south edge of Cornish, 368.
West Claremont station, 404.
High bridge (railroad) over the Sugar river, 405.
Railroad summit, ¼ mile north of Claremont junction, 478.
Claremont junction, 473.
Claremont station, 543.
Soldiers' monument — foot of shaft, 567.
Upper dam, Sugar river, 525.
Foot of falls, " 400.
Trisback hill, about 850.
Barber's mountain, about 950.
No. Charlestown station, 416.
Lowest point of railroad, in Beaver meadow, 314.
Springfield station, 374.
Skitchawaug mt., about 950.
Rattlesnake hill, about 650.
Oak hill, 625.
Charlestown station, 375.
So. Charlestown station, 302.
Fall mountain, about 1200.
Water-shed N. E. of do., 458.
Bellows Falls junction, 304.
Minard's pond, 592.
R. R. br., Saxton's river, 278.
" Governor's br., 257.
Cold River station, 259.
Walpole station, 277.
Westmoreland station, 512.
Westminster station, 264.

PLACES.	Distances in miles from Conn. lake.		HEIGHTS IN FEET ABOVE THE SEA.		
	Direct course (valley).	Course by the river.	Connecticut river.	Highest normal terrace.	Highest tributary deltas.
Hartland, ...	142	169.5	311	500	Lull's brook, 630–620, etc.
Windsor, ...	146.3	174.1	304	500	Mill br., 540.
West Claremont and Ascutneyville, ...	151.3	179.1	300	475, E. 455, W.	Sugar r., 540, N.; 520, S.
Claremont (on the Sugar river), ...			Sug. r. 525–400	Sugar r. 560–500	
Weathersfield Bow, . .	155	183.8	296	455, E. .50, W.	
North Charlestown, .	158	187.5	293	450	Lit. Sugar r., 475–530.
Springfield station, . .	162	191.5	289	450	Black r., 520. Beav'r br., 500.
Charlestown, ...	163.7	193.4	287	450	
South Charlestown, . .	167.4	197.5	284	450, E.	Williams riv., 500.
Bellows Falls, . . .	170.5	201	283–234	425, E.	
1 mile south, ...	171.5	202	230	416, W.	Saxton's riv., 486, N.; 466, S. Cold river. 465–475.
Walpole, ...	174	204.8	226	395	
Westminster, ...	175.2	206.2	225	380, E. 385, W.	
Westmoreland and East Putney, ...	181	213	218	350–360	Slab-hol'w br., 345–375.
Putney, ...	184	216.2	215	350	Sackett's br., 365–385.
Dummerston, ...	187	219.8	210	350	Kame-like, W. 420–440. Catsbane br., 420–440.
Brattleborough, . . .	192	225.2	200	341	Wh'tst'ne br., 409–425. Trib. to do. on S., 490.
North line of Vernon, .	193.5	226.7	197	340	Broad br., 425.
Hinsdale and Vernon, .	198	232.5	187	340	Hins. plain & N., 380–430. Ashuelot riv., 400; 365. W. of Vernon, 410.
South Vernon, . . .	201.8	236.7	180	325, E. 295, W.	
Northfield, ...	204	239	177	305, E.	360, E. 375–390, W.

Altitudes for reference, and remarks.
Grout's crossing, 258.
East Putney station, 295.
R. R. bridge, Sackett's br., 262.
Putney station, 257.
R. R. bridge, 1½ miles S., 240.
" " Salmon br., 238.
Dummerston station, 262.
R. R. over road, 1½ miles S., 271.
R. R. bridge, West river, 244.
Brattleborough station, 228.
" Catholic cemetery, 409.
Wantastiquit mt., about 1200.
School-house, ½ mile west of Hinsdale village, 373.
South Vernon junction, 261.
Ash. railroad bridge, 237.
N. L. " " 234.
Northfield village, 305.
Bernardston station, 353.

Slope of the highest normal terrace.

	Miles.	Ft. per mile.
Hall's stream to 3 miles north of Colebrook, .	6	10
" N. Stratford, .	15½	3
" Groveton, . .	12	9
" Lancaster, . .	7½	5
" John's river, .	7	2
" Passumpsic r.,	20	10
" Monroe, . .	4	15
" Woodsville, .	8	8
" 2 miles north of Orford, . .	16½	5
" Ely station, .	4½	0
" N. Thetford, in 2 miles h. n. ter. rises 85 ft.		
" Windsor, nearly level, . .	28	1
" Weath. Bow, .	9	5
" S. Charlest'wn,	12	0
" Westmoreland,	14	7
" Hinsdale, . .	17	1
" Northfield, .	6	6
Total distance,	189	4.3

Modified Drift along Lower Ammonoosuc River.

Interesting deposits of modified drift are found on the Lower Ammonoosuc river. Its course through the wide basin at the south-west foot of Mount Washington, descending more than 1,000 feet in six miles from the base of the mountain railway to the Fabyan house, is almost continuously bordered by large amounts of water-worn gravel, and sand becomes abundant in the last two miles below the Upper falls. These deposits appear to have been formed at the disappearance of the ice-sheet, principally consisting of material contained in its mass and set free at its melting. Their origin was like that of the finer alluvium of the lowland valleys; and their date was at the end of the long period in which nearly all our deposits of this kind were formed.

Modified drift of similar character occurs upon the South Branch. At the Crawford house, where several mountain torrents fall into the valley and form this stream, a great depth of very coarse stratified detritus has been brought down. This superficial deposit forms the water-shed between the Connecticut and the Saco, carrying it a third of a mile north-west from the rocky summit of the pass, which is at the gate of the Notch.

A well marked series of kames, or ridges of very coarse gravel, extends along the South Branch from about a mile north of the Crawford house nearly to its mouth. It appears again on the north-east side of the Ammonoosuc, between the mouth of this branch and the Fabyan house. Here it forms a single steep, narrow ridge, from 30 to 40 feet high, around which the river passes in a long southward bend. This ridge is conspicuously seen from the railroads on the opposite side. The mound known as the "Giant's grave," which was levelled down for the site of the Fabyan house, was a similar ridge about 300 feet long. This was noticed by Sir Charles Lyell, in his journey through the White mountains, who says it presented "the same appearance as those mounds which are termed 'osar' in Sweden."* Other deposits of the same kind lie between this place and the White Mountain house, at the north edge of the alluvial area. This series of kames appears to have been formed by a glacial river, which was fed from the melting ice-fields of the Mt. Washington and Mt. Willey ranges. Similar kames, which were also formed by glacial streams tributary to the Ammonoosuc valley, are seen along the Cherry Mountain road south from its summit.

That the ice of this area, near the end of the glacial period, moved westerly down this valley, is shown by abundant morainic boulders, which have been transported from Mt. Deception to the Twin Mountain house, where the glacier seems to have paused after its retreat from the lowlands and the valley below. The kames which we have described mark its diminishing extent at a later date. At both these dates great amounts of alluvium were brought down by its streams, forming a wide interval between the Fabyan house and the Lower falls, which fills what must at first have been a deep lake basin, and spreading out at and below the Twin Mountain house in an extensive low plain. The height of the former is from 1,560 to 1,550, and of the latter from 1,375 to 1,350 feet above the sea. Considerable deposits of modified drift occur at other points along the upper portion of this valley.

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* Lyell's *Second Visit to the United States.*

Below Littleton we find the alluvium continuous, and usually in large amount on one or both sides of the river to its mouth. This is a distance of nearly twenty miles, in which the river descends about 400 feet, having its mouth 407 feet above the sea. The highest terraces near Littleton are from 60 to 75 feet above the river, but scarcely any deposits occur for the first five miles above the low terrace, which is partly interval. Below North Lisbon both this and the high terrace, which sometimes widens into plains, are well shown. South-west from North Lisbon the high terrace is about 100 feet above the river; at Lisbon, about 125; at the east line of Bath, 150; at Bath village, 175; and one mile from its mouth, 200 feet, or 220 on its south side and 225 on its north side above Connecticut river. The slope of the ancient high flood-plain of the Lower Ammonoosuc was thus about 12 feet to a mile, descending but little more than half as much as the present river. The only kame observed in this lower part of its valley was a short ridge of gravel between the railroad and highway at the east line of Bath.

Modified Drift and Water-worn Rocks at Orange and Newbury Summits.

The lowest point in New Hampshire, upon the water-shed which divides the Connecticut and Merrimack basins, is at the summit of the Northern Railroad in Orange. Two rock-cuts, each about 30 feet in depth and together a quarter of a mile in length, were here made for the passage of the railroad through ledges of gneiss. Both these excavations were at the lowest points over which water could flow between these valleys. At the south excavation the top of the ledge on the east side shows in a distance of about fifty feet three water-worn cavities, 4, 6, and 12 feet deep, in order from north to south, one half of each of which has been blasted away. Still more remarkable evidences of water action, in the form of cylindrical pot-holes, similar to those at Amoskeag and Bellows falls, formerly existed here, but were destroyed in the work of rock-excavation. The most interesting of these was called "the well;" it was situated on the north ledge, and was described by Jackson as 11 feet deep, 4½ feet in diameter at the top and 2 feet at the bottom. It was originally filled with earth and round stones.* The height of the railroad here is 990 feet above the sea, being about 30 feet below the natural summits of ledge which were thus water-worn. The south ledge was three or four feet lower than the north ledge; and on both the water-worn portion was at their highest points, and thence extended down their south-east slopes.

When we consider the great amount of erosion which was effected during the ice age, it seems impossible that these pot-holes and evident marks of extensive water-wearing could have been preserved through this period, especially when we take also into account that any barrier, which had before existed to turn a stream across this place, must have been removed by this erosion. It becomes necessary, then, to inquire how such water-wearing could be produced during the melting of the ice-sheet.

The modified drift found on both sides of this summit shows us the probable answer to this question. Our examination extended from Grafton Centre to East Canaan. The stream which we follow northward nearly to Orange summit is the head of Smith's river. The first two miles to near Tewksbury pond show considerable areas of low, levelly stratified alluvium. From the north limit of this material we find no modified drift of any consequence for about two miles, extending over the summit, all the valley being ledge or glacial drift. No kame-like deposits were seen in this distance. On the north side of the north rock-cut a deposit of water-worn gravel lies against the ledge. At one fourth mile farther north-west we find a kame from 500 to 600 feet long and about 35 feet high, the top of which has nearly the same height with the top of the rock-cuts. Similar short kames, sometimes 1,000 feet long, generally single, and nearly in line with each other, extend thence for a mile along the south-west side of the railroad. This material is

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*Jackson's *Final Report on Geology of New Hampshire*, pp. 113 and 114.

mainly coarse, water-worn gravel, with the largest pebbles usually about one foot in diameter, sometimes interstratified with considerable sand. Deposits which are also apparently of kame-like origin, consisting of gravel and sand, border the hills on the south-west side of the valley to East Canaan. This distance of nearly three miles has but little descent, and to the north and west the country is nearly level for considerable widths in the valley, and not much lower than Orange summit. These areas are swampy, or are covered with low deposits of sand, which is also seen in patches on the hillsides from 30 to 40 feet higher. Large areas of low modified drift, often swampy, border the Mascomy river for several miles to the west. The heights of these points, in feet above the sea, are as follows: Grafton Centre, 871; Tewksbury pond, 904; Orange summit, 990; top of railroad cuts, natural surface, 1,020; East Canaan, 956.

The Merrimack valley, lying nearer than the Connecticut valley to the coast and outer limit of the great ice-sheet, and not being sheltered by a continuous belt of highland, was the first to become free from ice. It seems probable that the melting in the Merrimack basin proceeded north-westerly to this summit, which became the outlet from the melting ice-sheet over the nearly level area beyond. A long period appears to have followed before the ice disappeared from the Connecticut valley and along its bordering range of highland, of which Croydon and Moose mountains are the culminating points, so as at length to give the basin of Mascomy river a lower outlet to the west. The kames indicate the north-westerly retreat of the stream that descended from the glacial slopes; and the wide-spread, low alluvial deposits of Canaan mark the extent of the ancient lake, from which a large river nearly destitute of alluvium poured over the ledges of Orange summit into the Merrimack basin.

Newbury summit, on the Concord & Claremont Railroad, was probably in a similar way the outlet from the basin of Sunapee lake during a part of the Champlain period. The ledge beside the highway, 150 feet east from the rock-cut at this summit, shows a pot-hole 2½ feet in diameter, and the same in depth. With the present drainage no stream could exist to perform this work, which tells of a time when the ice-sheet had melted on the south-east and from the basin of Sunapee lake, while it still filled the valley of Sugar river, causing an outflow here to the east over the present water-shed. Along the half mile between this summit and the lake, kame-like banks of gravel and sand are found; but in general the shores of the lake are destitute of modified drift, being composed of till or ledge. The heights of these points, in feet above the sea, are as follows: Sunapee lake, low to high water, 1,090 to 1,103; Newbury summit, 1,130; top of railroad cut, 1,181; pot-hole, about 1,175; lowest point over which water could flow towards the Merrimack river, 400 feet south-west from the rock-cut, 1,161. It seems probable that when this pot-hole was formed, the lower avenue at the south-west was still filled with ice.

Another pot-hole, 10 inches in diameter and 3 feet deep, the origin of which we cannot explain, occurs about 20 rods north of Newbury station, at the shore of Sunapee lake, halfway between high and low water. There is no rivulet or depression leading to the lake at this point.

In Warwick, Mass., two miles north-east from the village, the drainage during part of the Champlain period was also over the present line of water-shed, which separates Ashuelot and Miller's rivers.* The current here was from north to south, as shown by an area 40 feet square of indisputably water-worn ledges, with numerous pot-holes, which are locally known as "Indian kettles." This place is near the lowest point of the water-shed, which is a swamp perhaps 25 feet below these water-worn rocks. While the pot-holes were being formed here, the lowest place over which water could have flowed was probably occupied by an unmelted portion of the ice-sheet, as at Newbury summit.

LITTLE SUNAPEE LAKE, NEW LONDON.

The peculiar form of this lake, as shown on the county map, led to an examination of its surface geology. It is a mile and a half long from east to west, and is divided into nearly equal parts by a kame-like tongue of land, which extends fully a half mile from north to south, leaving at the south shore only a shallow channel about 50 feet wide. It is principally surrounded by gently sloping hills of ledge or till, but a narrow margin of alluvium, 10 feet in height, borders its north-east shore. The materials of the dividing peninsula are sand or gravel, with boulders at its south end. Its width is less than 100 feet and its height about six feet, where it is joined to the north shore. The central portion is about a sixth of a mile wide and 30 feet high, gently sloping from the middle to the shores. This is used as a picnic ground, and is covered by pitch and white pines and white birches, the characteristic trees of our sandy plains. The southern portion is most like our ordinary kames, being mainly narrow, and in some places scarcely a rod wide. This peculiar accumulation of modified drift appears to be due to a depression formed here in the ice at its melting, into which these materials were carried by the glacial streams. Afterwards a hollow was left on each side at the disappearance of the ice.

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* Jackson's *Final Report on Geology of New Hampshire*, p. 282.

Ashuelot River in Keene and Swanzey.

The principal valley of Cheshire county has its widest development in Keene and Swanzey, as shown on Plate V. When the ice melted here, this basin contained for a short time a body of water somewhat larger and probably deeper than Sunapee lake, which soon became filled by the alluvium of floods which the retreating ice-sheet sent down by every tributary from north, east, and south. The city of Keene is built on the east portion of these level deposits, which are here two and a half miles wide, and extend with nearly the same width two miles to the north and the same distance to the south. The Ashuelot river flows through this basin, lying near its east side above Keene, but crosses to its west side in the north part of Swanzey. Its west portion in Keene is drained by the last four miles of Ash Swamp brook. Three miles south from Keene the Ashuelot river finds an avenue westward, along which it is also bordered by low modified drift for several miles. The straight valley, however, continues to the south through Swanzey, being occupied by the South branch and Great brook, with an alluvial area which decreases from one mile to one third of a mile in width. We thus find here a valley ten miles long from north to south, filled with nearly level deposits which are but slightly higher than the streams, and bordered by steep and nearly continuous ranges of hills, which rise from 400 to 600 feet upon each side. This alluvium consists almost everywhere of sand or fine gravel, perhaps extensively underlaid by clay, which is worked for brick-making near the south edge of the city of Keene. Its height is from 10 to 40 feet above the river; and the whole plain was originally of the same height with the highest portions, which still occupy the greater part of the alluvial area. These are generally separated from the lower interval by steep escarpments, which show that the difference in height is due to excavation by the river.

The only kames found in this area were several small irregular ridges of coarse gravel at Woodland cemetery in Keene. The railroad cut north of the bridge at South Keene shows successive layers of coarse gravel and sand. These are 40 feet above the highest plains, being the delta deposits of the branch which here enters the valley. South from this station for one third of a mile we have irregular ridges 40 feet high at a short distance west of the railroad, resembling kames in form, but scarcely differing from common till. In the south part of Swanzey we find occasional terraces, which are sometimes of coarse gravel, from 60 to 70 feet above Great brook, showing that much material at first deposited here was afterwards channelled out by this stream and carried northward to the wide low plains.

MODIFIED DRIFT ALONG THE PEMIGEWASSET AND MERRIMACK RIVER.

The river which drains the central portion of New Hampshire has a quite direct course slightly east of south. Its only departure in this state from the general direction is between the villages of New Hampton and Bristol, where it makes an offset of four miles to the west. This valley affords one of the few avenues for crossing the mountainous region. It begins in the deep gap of Franconia notch, between abrupt mountain walls, and it is at first closely enclosed by the high ranges which extend thence to the south. For twenty-five miles, or nearly to Plymouth, the valley is singularly straight, as is well seen from the summits of Lafayette and Cannon mountains, which rise at either side of its source; or it forms a beautiful view from hills in Campton, with its fertile intervals and well tilled farms extending for several miles, beyond which, at the end of its long vista, are the serrated mountains cleft by the notch (vol. i, p. 551). Its entire length from Profile lake, Franconia, to Massachusetts line, is comparatively straight, forming a continuous line of depression, which is a principal feature in the topography of the state. The upper and lower portions of the river which occupies this valley are known by different names. For more than fifty miles from its source this river is called

Pemigewasset, and the name Merrimack is applied to it only from the confluence of the Winnipiseogee at Franklin.*

The modified drift of this valley in New Hampshire is illustrated by Plates IV and V; these maps, like those of the Connecticut valley, show the extent of the intervals, terraces, and plains on both sides of the river, with their heights above the sea. The Pemigewasset river has a development of alluvium usually one half to one mile wide, which is bordered by high hills or mountains, forming a deep valley similar to that of Connecticut river along our western boundary. The modified drift of the Merrimack is usually one to two miles wide; its greatest development is in Concord, and in Litchfield and Merrimack, where it has a width of nearly four miles. The hills which border this part of the valley rise with comparatively gentle slopes, and the lowest points of its eastern water-shed are only 350 to 650 feet above the sea, unlike the continuous belt of highland which lies between this river and the Connecticut. After entering Massachusetts the Merrimack river turns east and north-east; and, with scanty deposits of modified drift, threads its way to the sea through a maze of hills which are composed of coarse glacial drift or till. Here the river has no connection with the principal questions in surface geology, which are quite different from those presented for study along its course in New Hampshire.

On the Pemigewasset river we find modified drift first at J. Guernsey's, in Lincoln, five miles from Profile lake. Thence for two and a half miles southward this consists of coarse gravel, much water-worn, extending one sixth to one third of a mile in width on the west side of the river. The mountains extend quite to the river along this distance on its east side. This modified drift has an irregularly smoothed surface, sometimes imperfectly terraced, with its outer margin at the north from 15 to 20, and at the south about 40 feet above the river. Its pebbles are from six inches to a foot and a half in diameter, and sometimes larger. Boulders also occur here and there, from three or four to ten feet in size.

A large plain of similar gravel occurs east of Pemigewasset river, on the north side of East Branch, having a height of from 30 to 40 feet above the river. Material for this plain was brought both from the north and east. Nearer to the river here we have a lower terrace only from 5 to 10 feet above it. In the excavation of the gravel deposits, the river has sometimes left numerous and well marked terraces, though small in extent, and differing but little in height. This is well shown near Tuttle's, in Lincoln, where four distinct terraces are seen between the road and the river, with from 3 to 5 feet escarpments, the highest being about 20 feet above the river.

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* The boundaries, area, and topographic features of the Merrimack basin are described in Vol. I, pp. 205, 212, 300, 306, etc.

The height of terraces in this valley was determined by levelling only as far north as to the mouths of East Branch and Moosilauke brook, which enter the Pemigewasset, from opposite sides, at nearly the same point. The river here is 710 feet above the sea, or only 242 feet higher than at Plymouth, eighteen miles farther south. Profile lake, its source, nine miles to the north, is about 1,950 feet above the sea, by barometric measurement, showing a descent to this point of more than 1,200 feet.*

The plains above the East Branch, not determined by the level, appear to be somewhat lower than the highest modified drift just south of this stream. This terrace has a height of 70 feet above the sea, and is ten feet higher on the west side. Thence for ten miles southward, or nearly to the south line of Thornton, the highest terrace of the river, commonly well shown on both sides, has a uniform continuous slope of 15 feet to the mile. This is nearly the same as the descent of the river, which has cut its way from 70 to 100 feet deep through its former wide, sloping flood-plain. These remnants, lying at corresponding heights on opposite sides of the river, and sloping with it in the regular lines of the upper terrace, are here very interesting, as seen extending for miles up and down the valley. Nowhere else in New Hampshire is the erosion of the modified drift, by which it has been shaped in terraces, so clearly and convincingly displayed. Here no doubt can remain that an original flood-plain, ten miles long, has been terraced as we see it by the excavation of the river. For most of the way along

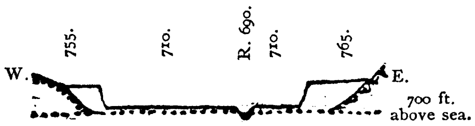

Fig. 17.—SECTION IN WOODSTOCK, 1½ MILES BELOW THE MOUTH OF EAST BRANCH. Length, ⅔ mile.

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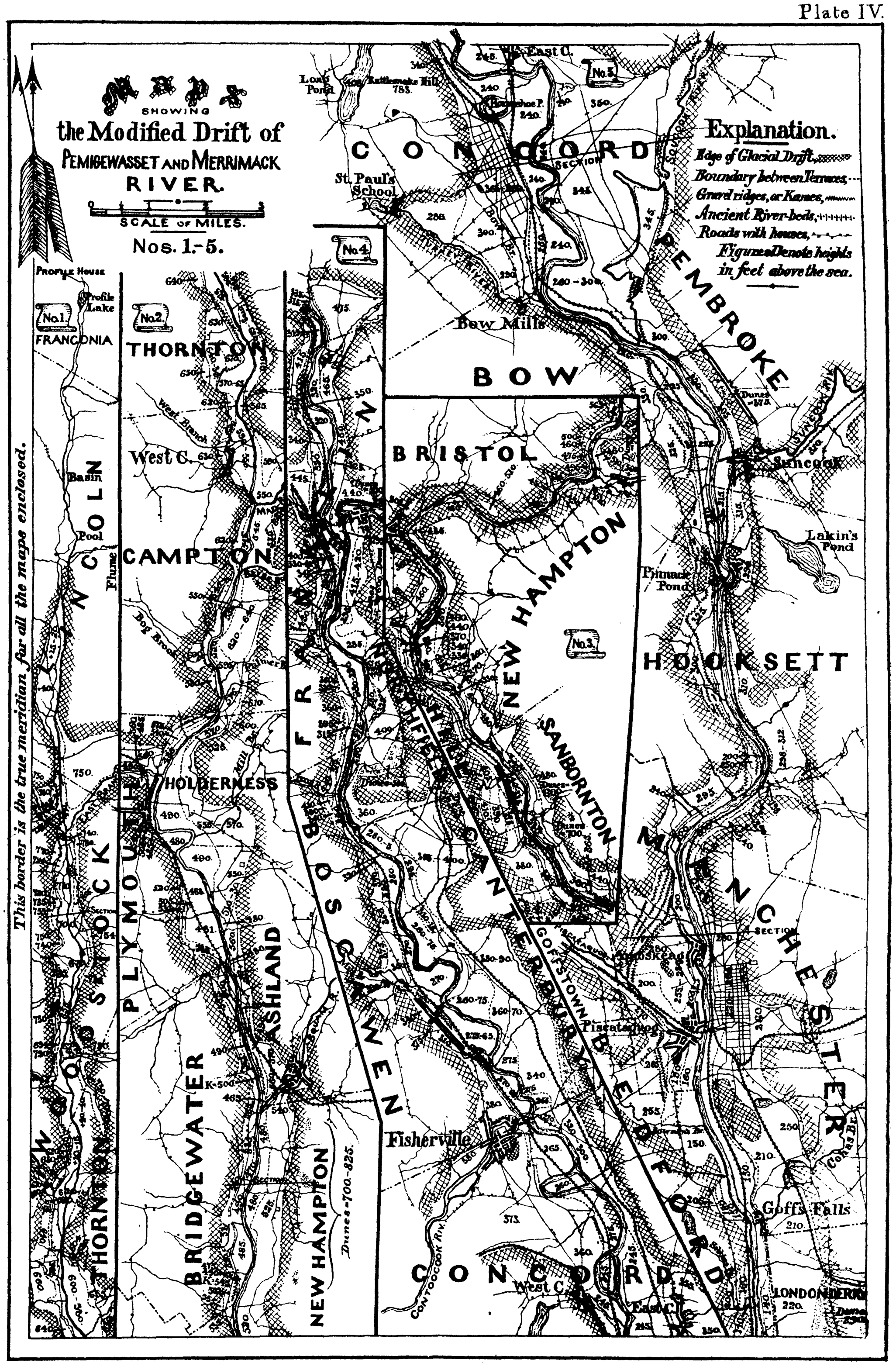
*The errors which occur in Vol. I, pp. 288, 308, and 322, in stating the height of Pemigewasset river at the mouth of East Branch, and of other points in this vicinity, arose by computing barometic observations from Thornton, which, through some mistake, is given 600 feet too high by Prof. Guyot, among the usually very correct altitudes published in his memoir on the "Appalachian Mountain System."


Maps
showing
the Modified Drift of
Pemigewasset and Merrimack
River.
0 1 2 3
Scale of Miles.
Nos. 1.-5.
Explanation.
Edge of Glacial Drift,
Boundary between Terraces,
Gravel ridges, or Kames,
Ancient River-beds,
Roads with houses,
Figures Denote heights in feet above the sea.
This border is the true meridian for all the maps enclosed.
No. 1.
No. 2.
No. 3.
No. 4.
No. 5.
Profile House
Profile Lake
Franconia
Lincoln
Basin
Pool
Flume
Woodstock
Thornton
West C.
Campton
Bog Brook
Holderness
Plymouth
Bridgewater
Ashland
New Hampton
Dunes 700-825.
Franklin
Boscawen
Fisherville
Contoocook Riv.
Concord
West C.
East C.
Bristol
New Hampton
Sanbornton
Northfield
Canterbury
Goffstown
Bedford
Long Pond
Rattlesnake Hill 783.
Horseshoe P.
St. Paul's School
Concord
Section
Turkey River
Soucook River
Bow Mills
Bow
Pembroke
Suncook
Lakin's Pond
Pinnacle Pond
Hooksett
Manchester
Section
Piscataquog
Goffs Falls
Cohas Br.
Londonderry
Dunes

HELIOTYPE

this distance, which lies through Woodstock and Thornton, we have two principal terraces, the higher being that just described, and the lower being wholly or in part overflowed by spring floods; but small intervening terraces are also of frequent occurrence.

All the modified drift of this valley, for the first seven miles to Woodstock village, is made up of gravel of different degrees of coarseness. Southward, banks and terraces of sand begin to appear; but gravel still predominates for a long distance below. The stream here frequently occupies a broad, shallow channel, paved with pebbles of all sizes to two feet in diameter, with little admixture of fine gravel or sand, which can accumulate only in deep or sheltered places.

Kames. In the south part of Thornton an interesting kame of coarse gravel is found on the west side of the river, between it and the highway. It extends north and south in a steep, sharp ridge about a fourth of a mile, and is less distinctly traceable for nearly a mile. Its top is 90 feet above the river, or 650 above the sea. Less than a mile farther south the road turns to the west around the steep face of a high plateau of kame-like gravel, which contains abundant pebbles up to a foot and a half in diameter. This deposit is of considerable extent, with its south-east portion nearly level, 660 feet above the sea, or about 100 above the river, but towards the north-west it has a broken surface, which in some places is 10 feet higher. It is from 30 to 40 feet higher than the normal upper terrace, which extends, with its regular slope of 15 feet in a mile, to this point, beyond which it also continues clearly traceable to the south. This higher plateau and the kame, which it resembles in material, date before the formation of the continuous high flood-plain. We must refer the latter to a time when the valley had become free from ice, while the former seem to belong to the period of its melting, owing their shape, in isolated plain and steep ridge, to the presence of ice-walls between which they were deposited.

In Campton the Pemigewasset receives two considerable tributaries from the east,—Mad and Beebe rivers,—which drain basins on the north-west and south-east of the mountain range that culminates in Sandwich Dome. South from the latter stream the upper terrace, increased in height by alluvium from the tributary, forms a pine-covered plain a mile long and half a mile wide. These "pine plains," appearing in a few places on the Pemigewasset and commonly along the Merrimack, we find to be one of the characteristic features of this valley. The modified drift of Campton occurs principally in the upper terrace, which has a normal height of 620 to 575 feet above the sea, or about 70 feet above the river, and in the interval or present flood-plain. At Livermore falls, near the south line of this township, the river passes through a deep, rocky gorge, with a natural fall of 22 feet. The foot of the falls is 483 feet above the sea.

In Plymouth and Holderness both the upper terrace and interval are finely shown; and the extent of the alluvial area, at one point a mile and a half wide, is greater than at any other place on Pemigewasset river. A beautiful interval extends for three miles below the mouth of Baker's river; at the north, mainly on the east, and at the south, on the west side. The broad, high plain belongs to Holderness, being on the east side.

Baker's River. A wide area of modified drift also lies along Baker's river below Rumney. For most of the way it is widest on the north side, reaching back at the widest place to Loon pond, a mile from the river. This likewise occurs in two heights, terrace-plain and interval, the former 40 to 50 feet above the river. The railroad extends over this alluvium nearly six miles in a single straight line.

The upper terrace, in Holderness, Ashland, and in the north part of Bridgewater, is 570 to 560 feet above the sea, or 100 above the river. Thence in six miles to New Hampton village it descends to 510 feet, or 72 above the river. It is best shown along this whole distance on the east side. There is almost always one lower terrace, and sometime several; but we find only small areas that are overflowed south from the large interval of Plymouth. Deltas higher than the normal upper terrace occur at two places near the north line of Bristol, and at the villages of Ashland and New Hampton. Spectacle pond, in the edge of Meredith, probably has its outlet by a subterranean channel, which extends under gravel and sand a mile to the west, appearing near the east edge of New Hampton village in several springs. The largest of these supplies a stream of very cold water two or three feet wide and a foot deep. Gravel ridges or kames bordering the Pemigewasset were seen in Ashland half a mile above the mouth of Squam river, and in Bridgewater at Eastman's falls, four miles farther south. No other deposits of this kind were observed between the townships of Thornton and Franklin.

Dunes in Merrimack Valley.

In the north part of New Hampton, and in many places for thirty miles southward to the north line of Concord, we find numerous dunes or sand-drifts lying at various heights on the east side of the valley, up to 300 feet above the highest terraces. Near their beginning, two miles south of Ashland, these dunes appear in large amount, and reach their greatest height. Here the sand-drifts, one to five feet deep, are strewn in a pathway 10 to 20 rods wide, which extends a fourth of a mile along the hillside, with a north-west to south-east course, rising 300 feet above the ordinary modified drift, or to a height of about 825 feet above the sea. These dunes of the Merrimack valley, like those along Connecticut river, occur only on the east side, consist wholly of fine sand, and lie in trains which ascend from the highest terrace in a south-east direction along the hillside. All these characteristics indicate their origin, through transportation by the prevailing north-westerly winds from the plains below, probably at the period when these had their greatest extent, prior to their excavation by the river, and, we may presume, before the appearance of a forest. They are usually made conspicuous at the present time, by being blown in drifts which are so constantly changing that they give no foothold to vegetation; but when they occur at considerable heights, we generally find the lower portion of the series grassed over, making the upper drifts appear isolated on the hillside. This is the case at the locality described in New Hampton. The upper part of this series, extending an eighth of a mile, is still in motion, and has been gullied and channelled by the wind often 3 to 6 feet deep over spaces 50 to 100 feet long, and carried forward, probably some portions 300 feet ahead and 50 feet higher, within fifty years. The whole train of sand-drifts at this

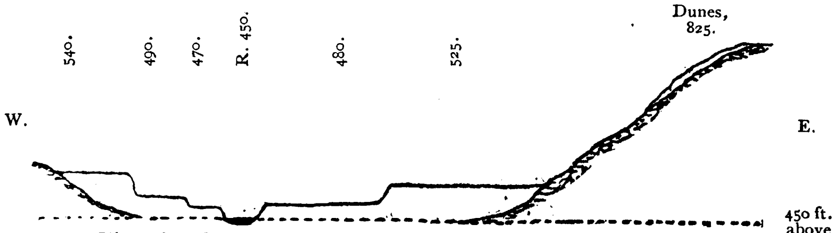


Fig. 18.—Section in Bridgewater and New Hampton.
Length, 1½ miles.

place is equal, by estimate, to a mass 1,000 feet long, 50 wide, and 2 feet deep, thus containing 100,000 cubic feet, or 5,000 tons, which have been raised by the wind an average height of 150 feet.

Another very good illustration of this transporting power of the wind is found in Sanbornton, a mile south-east from Hill, on a hillside which reaches a height 400 feet above the river, or 700 above the sea. Here the ancient dunes, as in New Hampton, have been swept forward anew since the land was cleared. The sand from a hollow 150 feet long, 40 wide, and 2 to 5 feet deep has been carried in long north-west to south-east drifts 200 to 400 feet farther, and 25 to 30 feet higher up the hill. The depth of recent excavation is shown by a large stump which has been thus undermined. The highest of these dunes have now reached the crest of the hill, covering the originally naked ledges; but they will not stop here, and at length may be found far beyond in the hollow on the east side of this first hill range.

Through Franklin and Northfield these dunes are numerous, occurring from 100 to 300 feet above the upper terrace of the valley, having their greatest altitude, 700 feet above the sea, a mile and a half north of Northfield depot. They are generally found, however, within 100 feet of the highest terrace: at such height they are well shown within a mile north and south from Franklin Falls, near Northfield depot, and in great abundance, extending more than a mile on the north and west sides of Hart hill. In the next five miles no dunes were observed, but they appear again at a similar elevation for a mile in the south part of Canterbury.

The instances of dunes found southward along the Merrimack are soon enumerated. They have a height of 70 feet, by estimate, above the highest terrace in Pembroke, on the west side of the village street, where they are covered with grass; they reach about the same height in Londonderry, two miles south-east from Goff's Falls, where they appear in large amount, forming irregular mounds and ridges; and at a few points in Litchfield and Hudson we find on the high plain, and scarcely raised above it, similar areas of barren, wind-blown sand.

From New Hampton to Bristol the river flows westerly, almost at right angles with its general direction, descending by a nearly continuous slope 86 feet in the four miles, which are the most rapid portion of its course south of the East Branch. The same rapids continue a mile or two below Bristol, so that the total descent in six miles from New Hampton bridge to the mouth of Smith's river is 118 feet, or from 438 to 320 feet above the sea. The westerly course of the Pemigewasset here corresponds to that of Connecticut river along Fifteen-miles falls. These are the only considerable deviations of these rivers from their general direction in the state; both portions are of rapid descent over till; they are alike bordered by sloping hills; and both differ from all the rest of these valleys in being well-nigh destitute of modified drift. Remnants of the original high flood-plain, now forming the normal upper terrace, traceable on both sides nearly all the way from the East Branch to Massachusetts line, appear to occur in the highest of two terraces at the mouth of Ten-mile brook; in a small, gently sloping plain about midway between New Hampton and Bristol; and in a similar area east of the highway a short distance north of Bristol. All these are on the north side of the river, and are from 510 to 500 feet above the sea. At several places along these rapids it appears probable that the channel has been cut through a considerable depth of till.

Bristol village is built almost wholly on till or ledge. Below Main Street bridge the fall in Newfound river is 105 feet, and its total fall from Newfound lake is 238 feet, the lake being 590 feet above the sea. The usual display of terraces again commences opposite Bristol, and thence the alluvial area extends, with the river, unbroken through the state.

At the mouth of Smith's river the highest terrace, 460 feet above the sea, is wide for a mile to the north, and extends in a narrow strip for the same distance to the south. Thence southward to Franklin we find remains of the same, principally on the east side, from 480 to 440 feet above the sea. In the south part of Sanbornton they form an extensive plain, 475 feet above the sea, probably slightly increased in height by the tributary alluvium of Salmon brook, which has cut a channel along its south-east side. From this plain a wide terrace (from 475 to 440 feet) extends south on the east side to Franklin, where the normal upper terrace is again shown on both sides of the valley, forming on the west the high sandy plain, 445 feet above the sea, which extends a mile north-west to Webster lake.

Lower terraces are numerous on both sides for a mile below Smith's river, the lowest being interval. West of Hill village an expanse three fourths of a mile long and a half mile wide is divided, by escarpments 15 and 20 feet in height, into three distinct terraces, the highest of which is 410 feet above the sea. A small terrace, 80 feet higher, is found on its west side. The highest terraces west of the river, well shown much of the way between Hill and Franklin, are from 40 to 60 feet below those on the east. This difference seems to be due to a deficiency in the amount of material supplied, the deposition being influenced by the current, and attaining its full height only on one side.

Kames. A short gravel ridge, projecting five feet above the plain of which it forms the border, and containing pebbles six inches in diameter, was seen in the north part of Franklin, on the west side of the road at one mile south from Hill village. Another gravel ridge, about 20 rods long and 35 feet above the plain on the west edge of which it occurs, was seen in Sanbornton near the river, a mile and a quarter south-east from the last. Both these short ridges are of typical kame gravel; they lie nearly in the middle of the valley, and their heights are about the same, the northern being 385 and the southern 365 feet above the sea. It is not improbable that these are remnants of a formerly continuous kame.

This coarse gravel was next observed at a railroad cut on Bristol Branch, one mile above Franklin depot; an excavation of it may be seen in Franklin village, just north of Webster brook, at the west side of the street; and it is again exposed in the same way a short distance south of the depot. It also forms a ridge, nearly covered by the fine alluvium of the upper terrace, on the east side of the river, one fourth of a mile above the bridge. Southward in this town kames were noted at two places on the west side.

At Boscawen village portions of a well marked kame form the escarpment of the plain, which has about the same height, near the north end of the street and south from the road to the bridge. One mile farther south we find between the highway and the railroad a ridge several hundred feet long, the north part of which is composed of coarse water-worn gravel, while its southern portion seems to be unmodified till.

The ancient highest flood-plain of the Merrimack from Franklin to Massachusetts line is everywhere well shown by the conspicuous upper terraces. Along much of the way these expand on one or both sides into wide, sandy "pine plains," so called because their principal wood-growth consists of white or pitch pines. These are sometimes accompanied by a thick and tangled undergrowth of scrub oaks, which, with the pitch pine, flourish best on the barren plains. Their surface is very level, with a regular but very slight slope, which amounts to nearly the same as the descent of the river. In some places this may be finely seen, as at Concord, where a level set at the same height with the plain on the east side commands a view of its edge for three miles along the river, in which distance it is seen to slope only a few feet, with no undulation to break its straight line.

It is worthy of notice, that in this entire valley, including Pemigewasset river, no important deltas are found. This is in remarkable contrast with the Connecticut valley, where the regular line of the river's highest alluvium is hardly traceable, or is less readily seen much of the way, because of the extensive higher deposits of tributary streams. In this valley such deposits have helped to fill extensive areas, as in Concord, for which it would seem that otherwise the supply must have been deficient, and sometimes they slightly increase the height of the upper terrace, but in no place do they form, as on the Connecticut, frequent and well marked terraces above this normal line. The Merrimack valley is wider than that of the Connecticut, giving room for its ample plains; and its sides slope more gently, forming lower ranges of hills. Its tributaries partake of the same character, and also have a less rapid descent than in the Connecticut basin, allowing the deposition of large amounts of alluvium along their course, as on Baker's, Contoocook, and Suncook rivers. The modified drift of the Merrimack is rendered more simple, but not less instructive, by being free from the confusion of associated tributary deposits.

At Franklin the upper terrace is well shown upon both sides of the valley. It has considerable fall in a short distance here, being 445 and 440 feet above the sea at the north side of Webster brook and Winnipiseogee river, and descending in less than a mile to 430 and 420 feet at their south sides. The mouth of Winnipiseogee river is 269 feet above the sea, the Pemigewasset having descended nearly 30 feet in its last mile, so that the upper terrace here has a height 150 to 175 feet above the river. The highest alluvium for eight miles northward, extending through Sanbornton and including the large plain north of Salmon brook, has an equal elevation above the river, which is greater than in any other portion of this valley. In the next nine miles below Franklin the upper terrace falls to a height of 125 feet above the river, which continues for more than 20 miles to the north part of Manchester, the highest terrace seeming to descend most rapidly near the present falls of the river, so that a nearly uniform height above the river is maintained.

Opposite the Webster place, two and a half miles below Franklin, this high terrace presents a quite remarkable form. Its base is washed by the river, which here sweeps eastward, leaving a fertile low terrace of large extent on its west side. Ascending from the river to the east we have first the steep escarpment, more than 150 feet high, the top of which has nearly the normal height of the upper terrace; but this, without any level space as usual, is succeeded by a sloping surface of sand, which extends to the road, and rises about 120 feet in less than a fourth of a mile, appearing in all except its slope like an ordinary terrace. Very high sand-dunes occur on the hill south-east, and it seems probable that this unusual slope, rising more than 100 feet above the normal height of this terrace, was heaped above it by the north-west wind, soon after the time of its deposition. A similar sloping surface of the upper terrace, but much less in amount, is also seen for a mile or more north and south, and at many other points along the river. Between one and two miles farther south we find the greatest profusion of dunes observed in New Hampshire, the highest of which, however, do not exceed 250 feet above the river.

In Canterbury the upper terrace spreads out into plains, which are at some places a mile wide. The Boston, Concord & Montreal Railroad through the town is upon these high plains, while the Northern Railroad, in Boscawen and Concord, lies on the lowest terrace, being embanked much of the way to raise it above the high floods of spring. The plains of the south part of Canterbury, extending one mile into Concord, show an unusually rapid continuous slope, amounting to 80 feet in four miles, or from 130 to only 50 feet above the river, which is here 250 feet above the sea. The north end of this slope appears to be at the normal height, representing the level of the river at the time of deposition of these plains, while the terrace of Boscawen village, on the opposite side of the river, is 40 feet lower. The south end of this slope is about 70 feet below this normal line, which is here shown on the west side in the plains north and south of Fisherville.

Boscawen village is built on the south end of a similarly sloping terrace three miles long, in which distance it falls 30 feet, and we find 30 feet more fall of the same terrace in less than a mile along the village street. The whole of this terrace is below the normal height, showing a deficiency of 15 feet at its beginning, and of 40 feet at the north end of Boscawen village. It appears as if the supply of alluvium was insufficient, and the direction of the current at first caused it to be deposited in greatest amount at one side, without filling the valley. South of Boscawen the supply of material became still more inadequate, and the lower portion of the sloping plains east of the river was probably 60 feet below the surface of water, which was held back by the extensive plains of Concord, derived in large part from the Contoocook and Soucook valleys.

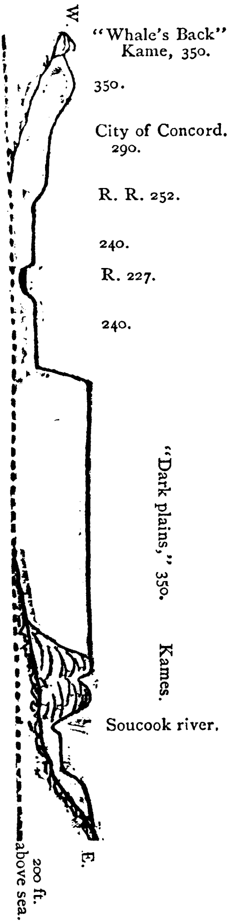


Fig. 19.—Section in Concord. Length, 3½ miles.

Although the plains in Concord were obviously brought in from tributary sources, they belong to the ancient flood-plains of the Merrimack, since they form a portion of the series of high terraces and plains which extends with a slightly varying but unbroken slope along this whole valley. Even if no modified drift were supplied, except from the upper part of the main valley, irregularities of slope, as in Boscawen and Canterbury, with increased height below, as in Concord, would still be produced by an irregular rate of retreat of the ice-sheet, allowing long and abundant deposition in some portions, but much less in other portions of the same valley. In this way we must explain the sudden and permanent increase in height of the upper terrace of Connecticut river at North Thetford (p. 36). Probably this cause was combined with the aid of tributaries to produce the high plains in Concord and southward.

Between Fisherville and West Concord these plains have a large extent, lying on the south side of Contoocook river. Their northern and western portions are 125 feet above the Merrimack river at the head of Sewall's falls, but they become slightly lower at the south. The mouth of Contoocook river is 249 feet above the sea. Its descent through Fisherville, in the last mile and a half of its course, exceeds 100 feet. By the Borough dam, at the head of these falls, this river is held level to Contoocookville in Hopkinton, six miles in a direct line. Along this distance and beyond we find extensive alluvial areas at small elevation above the river, continuous with these plains in the Merrimack valley. A description of the modified drift of Contoocook river will be hereafter presented.

The most extensive plains in Concord, and indeed in this entire valley, lie on the east side of the Merrimack between it and the Soucook river. They extend along Merrimack river six miles, from above East Concord to the mouth of the Soucook. Their area of greatest width, which exceeds two miles, is opposite the city, being known as the "Dark plains." The channel which has been excavated by Soucook river is very crooked, lying at first along their east edge, but at three miles from its mouth deviating towards the middle of the plains, and again returning eastward and southward. This excavation is 50 to 125 feet in depth, with areas of low terrace at its bottom bordering the river. The greater part of this large expanse of plain is very level, with occasional gullies, but with scarcely any undulations rising above the general surface. Its slope, in nearly four miles from its north-west limit to opposite the south part of the city, is only 10 feet, with a height 130 to 120 feet above the river, or the same above the river as the plains north and south of Fisherville, their difference in absolute height being equal to the descent of the river at Sewall's falls. Farther south the slope of the plain becomes more rapid, descending 50 to 75 feet in about two miles, the highest portions at the south end being about 100 feet above the mouth of Soucook river, which is 199 feet above the sea. The total descent of the Merrimack in Concord is thus 50 feet, of which 20 feet are at Sewall's falls, four miles above the city, 5 feet at rapids a short distance above the mouth of Turkey river, and 20 feet at Garvin's falls, three fourths of a mile below.

In Boscawen and Canterbury, and through Concord, the lowest terrace for 12 miles occupies a wide area, of which a large part is overflowed by the high water of spring, forming the only extensive intervals on this river south of Plymouth. These are from a half mile to one mile wide, their fertility being in marked contrast with the barrenness of the "pine plains." A fine view may be obtained in Canterbury and Concord from the edge of these plains, whose high bluffs descend abruptly a hundred feet, overlooking the level bottom-lands and the windings of the river for miles north and south. In other parts of its course the river is confined between terraces, which prevent an irregular route. Its meandering course here was signified by the aboriginal name *Penacook*, or crooked place, which was applied to the south part of this territory.

Ancient river-beds are indicated at many places by shallow ponds, which lie in long and frequently curved depressions of the interval, often near the foot of the higher terraces, and but slightly elevated above the river. One of these is seen on the east side of the railroad, a mile south of Boscawen depot; one lies on each side of the river just south of Sugar Ball bluff, near Concord; and others occur east of the south part of the city; but the largest and most interesting is Horseshoe pond, at the north end of the city, which is shaped like a crescent, being a half mile long, nearly as wide as the present channel, and six feet above the ordinary height of the river. This pond is crossed by the Northern Railroad. Its middle portion lies at the foot of a higher terrace, against which the river once swept its full current. The nearest point of the present channel is a half mile distant at the north, where the river bends and now directs its current against Sugar Ball bluff, a mile and a half northeast from Horseshoe pond. The date of these changes cannot be stated, except that it was before the first settlement here, 150 years ago.

Recent Changes of Merrimack River in Concord.

Dr. William Prescott, of Concord, in 1853 collected dates and measurements of many remarkable changes in the channel of Merrimack river which had taken place since a careful survey of this portion was first made in 1804.* From this record it appears that below Federal bridge, near East Concord, the river has changed its entire width from south-west to north-east, and a third of a mile to the east it has changed more than its width in an opposite direction. On the east side of the "Fan" or broad interval opposite the north part of the city, the river flowed in 1804 by a very circuitous route 460 rods, which was shortened to 150 rods by great freshets in 1826, 1828, and 1831, which cut a direct course across two peninsulas then known as Sugar Ball point and Hale's point. Ponds already mentioned occupy portions of the old channel. Ten years later, Dr. Prescott reported the rapid undermining of Sugar Ball bluff, 125 feet high, of which the river had carried away, between 1853 and 1863, a mass 80 rods long and 40 rods wide. This erosion is still going forward, being aided by springs near the foot of the bluff. At Davis's bluff, about a mile south, a width of three rods was swept off in 1863 in three days. Erosion at this point has continued thirty years, requiring a dwelling near the edge of the bluff to be several times moved, and the road changed.

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* *Collections of N. H. Historical Society*, vol. vii. At the time of publication of this volume, in 1863, a statement was added describing subsequent changes to that date.

In the same volume is also found a valuable address on "The Valley of Merrimack," by Joseph B. Walker, Esq., describing its physical features, and recounting its earlier and later history.

The same undermining of the high plains by the river is also going on at several places north and south of Fisherville. One mile south-east from Boscawen bridge, the plain, 110 feet above the river, is fast wearing away, and portions of it 10 feet wide and 150 feet long had fallen in 1875 10, 20, and 40 feet, remaining nearly level, so that their sapling pines, 10 to 30 feet high, were still upright and growing on the side of the steep sand-bluff. These would be carried away, to be followed by new slides during the next high flood. One mile farther south, and at other points below Fisherville, a similar rapid erosion was observed. A quarter of a mile north-east from Fisherville bridge, a bluff, which has been so recently undermined that it is not yet grassed, is now separated from the river by a wide area which does not exceed five feet above the ordinary height of water. These recent incursions of the river upon the plains, and the rapid changes in its channel upon the intervals, washing away yearly from one bank and adding to the side opposite, leave no doubt that the river has flowed at the foot of the bluffs along their whole extent, occasionally making a deep excavation beyond its ordinary bounds, as on the east side south of Sugar Ball bluff; that the high plain once filled the whole valley; and that the river has swept many times from side to side over the space occupied by its lower terraces and interval.

Important changes in the channel of the Merrimack have also been made artificially in Concord. One mile south of Fisherville depot the course of the river was formerly in a westerly curve, passing around Goodwin's point, two thirds of a mile from its direct course. At the west end of this detour it was fast undermining a long line of bluff 125 feet in height. When the Northern Railroad was built, in 1846, the river was turned, to avoid bridging, into a new channel, by which its course was made straight, being shortened fully a mile. Its old channel remains filled with water, except at its south-west bend, which is nearly silted across; and the erosion of the bluff at times of freshet is greatly diminished. Farther south, at about three miles above the city, the river flowed in two channels, of which the west one was largest, enclosing Sewall's island. The railroad was built across this island, reaching and leaving it by embankments instead of bridges, for which purpose the west channel was dammed, when the river is said by Dr. Prescott to have swept away, to widen its east channel, a width of 20 to 25 rods of its bordering interval for two thirds of a mile.

Dr. Prescott mentions that, in cutting the new channel across the base of Goodwin's point, "the workmen, at the depth of about 12 feet, struck upon a bed or stratum of vegetable matter, consisting of leaves, branches, and trunks of small trees, the latter from three to six inches in diameter, the form of which was perfect, and the bark distinct. This vegetable deposit was found embedded in a stratum of fine blue sand, which at first sight was mistaken for blue clay, and was from one to three inches in thickness. The trunks and large branches were recognized as belonging to the natural order coniferæ." He also describes, from an excavation at the gas-works in Concord, supposed "fragments of the roots, trunks, and branches of trees. They were found deposited in a stratum of ferruginous sand (composed of sand and oxide of iron); and in some instances the fragments of roots and branches of trees were completely incased in a firm coating or crust of the oxide of iron and sand from one eighth to one half an inch in thickness." This was at a depth of ten feet. It appears probable that these were cylindrical concretions of oxide of iron, which often show concentric rings, almost exactly imitating the annual layers of wood. These were found abundantly in the excavation for laying the water-works main, in 1872, near the south line of the city farm, and may be occasionally met with in any alluvial sand.

Between West Concord and the city the upper terrace is from 10 to 30 feet lower than on the east side of the river. The greater part of the city, and a large area southward to Turkey river, are slightly lower, being about 300 feet above the sea, or 75 above the river. In the west part of the city the modified drift, composed of sand or fine gravel, rises unterraced into irregularly sloping hills, the highest of which, crossed by Church and School streets, are 367 feet above the sea, being higher than the plains of the east side.

Kames in Merrimack Valley.

Interesting kames are found at Concord, where they form the uneven east part of Blossom Hill cemetery, and extend south in a nearly continuous series, composed of irregular, short, low ridges and mounds, always with north to south trend, to the intersection of Franklin and High streets, and thence on the same course to Centre street. The south portion of this series is a single steep ridge, from 25 to 40 feet high, called "Whale's Back," which originally extended a quarter of a mile from near the corner of Centre and Pine streets to that of Warren and Liberty streets. The north half of this has been used by the city in making and repairing streets; for which this gravel, when screened to remove its coarse pebbles, forms an excellent surface, and ultimately the whole ridge will thus be removed. The material of "Whale's Back" is mainly very coarse gravel, containing abundant pebbles up to one foot, while the largest reach two or three feet in diameter. These are always well rounded, having the characteristic water-worn form,—not that of glaciated boulders, which are distinguished by flattened, striated sides, with rounded corners and edges. This water-worn gravel lies in a steep, narrow ridge, a section of which usually shows an indistinct anticlinal bedding. The rounded boulders, pebbles, and fine gravel are almost indiscriminately mingled through the whole mass, often with very scanty streaks of sand or other lines of stratification.

This series of kames lies at the west margin of the wide alluvial area, resting upon till 100 to 125 feet above the river. Its extent is a mile and a half, having the same course with the valley. No kame-like deposits were discovered along the east side of the river in Concord, the whole mass of the plains being fine alluvium. Similar ridges were next found just below the mouth of Soucook river, exposed by railroad excavation on both sides of the Merrimack. The kame here cut through by this river is a portion of a series which extends twenty miles from Loudon to Manchester.

In materials, arrangement, and stratification this principal line of kames in central New Hampshire is like the short series just described, but unlike the long single kame of the Connecticut valley. The greater part of these kames is of very coarse, water-worn gravel, with pebbles six inches to two feet in diameter, disposed in irregular ridges from 40 to 100 feet in height, of southerly trend parallel with the valley, a section of which usually shows an indistinct stratification. This, however, varies occasionally to coarse angular materials, mainly consisting of unworn rock-fragments up to four or five feet in size, with no evidence of water action. A mile south of the Pinnacle in Hooksett a gradual transition is seen from water-worn gravel to this morainic material, which continues about a sixth of a mile and then changes back to modified drift, the whole forming a continuous ridge. Other portions of these kames contain considerable amounts of sand or fine gravel, alternating in irregular layers with the common coarse gravel, thus showing very well marked stratification, which is always inclined, being usually anticlinal or arched in the section of a ridge.

This Merrimack series differs notably from that of the Connecticut in being frequently composed of several ridges, nearly parallel to each other, with long irregular hollows between them which sometimes contain ponds. About half is thus made up of two or more parallel ridges, while the other half, in separate portions of a mile or two each, consists of a single ridge. Upon the Soucook river these kames are repeatedly cut through by its present channel, as also near its mouth by the Merrimack, but in the fourteen miles farther south they lie wholly on the west side of the Merrimack, often near the edge of its alluvial area.

The north end of this series has not been fully examined. Its first appearance noted is on Pine brook, half a mile west of Loudon village, where north-west to south-east ridges of coarse gravel occur. They were also seen on the south-west side of Soucook river, near the first bridge below this village; thence they probably occur near the river southward, but have not been explored for the next mile and a half, to near Richardson's mill in Concord. For a fourth of a mile north from this mill, and five and a half miles southward along the Soucook to its mouth, these ridges have been carefully traced, and are found well developed, rising 40 to 100 feet above the river, and nearly continuous, sometimes single, and again two or three parallel and of equal height. These kames, for the first three miles, lie close to the river, almost wholly on its west side. The material is prevailingly very coarse, but for the most part plainly water-worn, with the largest pebbles or rounded boulders two or three feet in diameter, and it occurs in steep, narrow ridges 40 to 75 feet high. The river above Richardson's mill is 307 feet above the sea; hence these kames do not exceed 400, and those west of Loudon are probably about 450 feet above the sea.

At Clough's mill, three miles above its mouth, the Soucook departs from its general course, crossing the line of kames, and turning with a right angle one mile to the west. Below this point the river does not follow, as before, the eastern border of the plain; but we find that the kames continue in a nearly straight course close to this east boundary. For a mile and a half from Clough's mill the kame lies on the east side of the road. In the first half mile of this distance we find a single steep, narrow ridge of coarse, water-worn gravel, 20 to 40 feet above the adjoining plain. Sections of this ridge are exposed by the river at Clough's mill, and by a cut across it for a new road at a short distance south. In the next mile we find the same coarse gravel, lying partly in the form of a ridge, but not so prominently, and partly in a somewhat irregular terrace.

One mile above the mouth of the Soucook, where it comes near the highway, a distinct gravel ridge occurs on its east side; and on its opposite side we have two parallel ridges, separated by a hollow, but with the top of the west one the same in height with the adjoining plain. The largest pebbles seen in this ridge were one foot in diameter. Thence for nearly a half mile no kames are found; but after passing the lowest bridge on this river they are well shown on its east side to the railroad near its mouth, forming a broad ridge of gravel, with pebbles up to a foot and a half in diameter. The direction of this ridge points to the continuation of the series on the opposite side of Merrimack river.

A fine section of the kame has been exposed by excavation for the railroad at the point where it reäppears in Bow, one fourth of a mile north of Robinson's station. Here the water-worn gravel, containing none but rounded pebbles, the largest of which are two or three feet in diameter, forms a well defined, anticlinally stratified ridge about 40 feet high, which is entirely overlaid by the later sand deposit of the ordinary terrace.

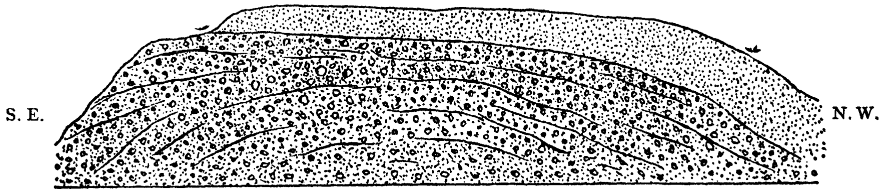

Fig. 20.—Section of Kame overlaid by Sand, ¼ Mile north of Robinson's Station. Scale, 1 inch=50 feet.

Thence the series extends for a mile in a single ridge, which is partially and at some points wholly covered by the fine alluvium. In the next mile we have two ridges nearly parallel, but somewhat irregular in course and in height. The intervening hollow contains a small pond. These ridges form the east border of wide plains, which have nearly the same height with the kames. The sand of the plains is shown to be the most recent deposit by its superposition. It appears that, after the gravel ridges had been formed, great amounts of sand were swept into the valleys; but spaces nearly enclosed between parallel ridges were often protected from this deposition. In the subsequent excavation of a large portion of this sand by the river, producing the lower terraces and its present channel, these coarse ridges have been a barrier protecting the plains on their west side. Opposite the mouth of Suncook river, the eastern of the two ridges lies on the south-east side of a small brook;—here we again found for a few hundred feet numerous angular rock-fragments, of dimensions from one to two and a half feet, while other portions, so far as seen, were of water-worn but often very coarse gravel. A short distance farther south the series is suddenly interrupted, and its direct course is occupied by a high, ledgy hill. An irregular high terrace of gravel and sand on its east and south-east sides may represent the kame. After a mile the series reäppears in its characteristic ridges, and continues five miles quite irregularly and of varying material, but plainly one connected series to its next gap, which begins opposite Martin's Ferry.

In Hooksett the kames are well shown for a mile north from Pinnacle pond. Several small ponds lie in the irregular hollows at the sides of these ridges. A well marked kame forms the east border of the high terrace west of Hooksett village and north-east from the Pinnacle, directly east of which it could not be traced, but it reäppears in a ridge on the south side of the road south-east of this quartz peak, thence turning south-west towards the principal range of these kames, the direction of which seems to lie from north to south across Pinnacle pond. The locality of greatest irregularity in respect to shortness of ridges, inequality in height, variable course, and diverse material, found in this whole series, is the first half mile south from this pond. The scale of the map, however, does not permit details to be shown. A deep, winding hollow extends along the west side of the main ridge from within one fourth of a mile of the pond to a junction with the valley of a small brook nearly a mile south. A considerable portion of this hollow seems to be due to excavation; and for the next mile southward, where a single nearly straight ridge parallel with this brook constitutes all that we have of the series, the plain, which is 30 to 40 feet above the top of the ridge, has been so washed away that a wide hollow has been formed at both sides.

Here the plain is sand or ordinary gravel, but the kame is mainly composed of the very coarse, water-worn gravel, which forms the principal portion of this series. This, however, is here found changing into coarse unmodified material, in which angular boulders, mostly of gneiss or granite, two to five feet in their dimensions, occur almost as closely packed together as possible, with the gravel of the interspaces unmodified by the wearing of water. This forms a well defined narrow ridge, 25 to 40 feet high, which continues a sixth of a mile, or perhaps more, when it changes again to materials rounded and sorted by water, and wears the usual aspect of these kames.

Next below this long single ridge the brook finds a passage to the river; and a very remarkable assemblage of kames, partly water-worn and partly angular, succeeds, covering an area half a mile long and one fourth of a mile wide, with short parallel or irregular ridges, most of which trend from north to south. These ridges are nearly level-topped, with intervening hollows at the north 30 to 40 feet deep. Near the middle of the area a deep hollow runs transversely across the course of the kames from west to east. South from this the space between the ridges has been mainly filled with alluvium, forming a plain upon which the position of the kames is easily traced by their lines of coarse gravel. Occasional boulders, apparently brought by floating ice, lie on the surface of this plain. One of white quartz, six feet long, has thus travelled more than two miles from its parent ledge, which was probably the Pinnacle.

The course of the kames now turns eastward and then westward at the end of a mile, conforming to a bend in the valley. At the north this curve consists of a single low ridge, which is in large part composed of angular rocks up to one or two feet in size, lying between the road and the river. Where it turns to the south-west, opposite Martin's Ferry, we have a broad gravel hill, in which also many of the stones are angular, while other portions are water-worn. Thence for two miles southward the kames have been wholly carried away by the river, which has its channel directly in the line of their course.

On the east side of the river this series may be represented in the high plain one mile north of Martin's Ferry, which has irregular ridges and hollows, and is composed of gravel with pebbles six inches to one foot in diameter; but a large area of similar gravel, extending thence to the north-east, seems to be clearly a tributary deposit. An undoubted remnant of the series occurs half a mile south from this station, in a coarse gravel deposit, showing oblique and irregular stratification, which has been excavated for railroad ballast. Occasional angular boulders, three to six feet in size, which must have been brought by floating ice, were noticed in the same terrace.

In Manchester a fine display of these kames begins at the west side of the river road, a mile and a half above Amoskeag bridge, and their greatest development in the whole series is thence south-west to Piscataquog river, where they cover an area two miles long by one fourth to half a mile wide, closely adhering to the west side of the widened valley. We find here as many ridges as can well occupy this space, all lying in the same course, which is that of the series, and having a comparatively uniform height. Some of them probably extend almost the entire length of this area, while others are short or broken by gaps. Their material is principally water-worn gravel, sometimes as fine as prevails in the Connecticut kame, and interstratified with sand, but more commonly very coarse, as is characteristic of this series. Other portions are unmodified, containing angular stones; and large boulders are occasionally found. Three long hollows, varying from 30 to 50 feet in depth, one being wholly enclosed, lie between these kames for a half mile at their north end, beyond which the hollows have been filled with fine alluvium, producing a nearly level plain. Southward, many irregular long hollows are found, one of which contains a pond. An ancient channel, occupied by the whole or a part of the Merrimack when it first began to excavate its highest plain, extends along the south-east side of this area of kames. Rock Rimmon lies a quarter of a mile farther south-east, and the extensive plain around it is destitute of kames.

This series makes almost a right angle where it is crossed by the Piscataquog river, nearly two miles above its mouth, and turns south-east for a mile, consisting of a single ridge of water-worn gravel, which lies near and parallel to the river. It is well exposed at this angle by excavation for the Manchester & North Weare Railroad a short distance west of its bridge. An exploration of the Piscataquog valley for two miles farther west showed high and low terraces of fine alluvium, but no kame-like deposits. The south-east course of the kame with this river would have led to the conclusion that its origin was from this tributary valley, had not the whole series been traced and found at other places as here closely following the west side of the Merrimack valley.

Near Piscataquog village the course of the series turns to the south, crossing the New Boston road about an eighth of a mile east of the cemetery. This road passes through a gap in the principal ridge, which both on the north and south is filled almost as compactly as possible with angular fragments of rock one or two feet in size. Through this gap a portion of the river formerly flowed, and its ancient channel extends a mile to the south, lying on the west side of the kame. South-east from this gap, and east of the coarse ridge of angular materials, we find a small plateau, which belongs to this series, and is composed of well-rounded gravel, the largest pebbles having a diameter of two feet. A thin covering of sand forms the surface here, but excavations show the coarse gravel, which is prepared by screening for the manufacture of concrete pavement. This series terminates within a half mile to the south. After being traced continuously six miles along Soucook river and fourteen miles along the west side of the Merrimack, it stops here, and similar deposits were next found fourteen miles below in Hudson and Nashua.

These kames at their beginning reach a height about 100 feet above the Soucook river, or 400 to 450 feet above the sea, and they continue at nearly the same height above the river to its mouth, where they are 300 feet above the sea. Along the Merrimack they are 325 to 265 feet above the sea, or 100 to 125 above the river. The only point where a ridge is found much lower than this is at the eastern curve of the series, in the south part of Hooksett, where it is only about 50 feet above the river. The large area of kames in Manchester rises 100 feet above the head of Amoskeag falls; and the ridge and plateau south-west of Piscataquog are 15 feet lower, being 142 feet above the foot of these falls, and 265 feet above the sea. With an irregularity in height which is almost constantly changing within limits of twenty-five feet, we thus find these kames, as a series, preserving a comparatively uniform elevation above the present river, which is about the same as that reached by its ancient flood-plain.

The origin of these remarkable ridges must be explained in a similar manner with that of the long single kame of Connecticut river. The date of their formation was at the melting of the great ice-sheet. The comparatively fine gravel and frequent layers of sand in the Connecticut kame attest a slow melting of the ice, long water-wearing of its material, and deposition from a moderate or even gentle current. The Merrimack kames, as far north as to Loudon and Concord, indicate a much more rapid departure of the ice, which allowed less time for the formation of rounded gravel, and was attended by strong currents. A section of the Connecticut kame shows, by its alternation of coarse and fine materials, that successive summers and winters were occupied in its accumulation. The same appearance is often seen in the Merrimack series, but frequently a section of these kames is without very definite stratification; and all its materials, which are then very coarse but commonly much water-worn, appear to have been deposited by a nearly uniform and very powerful current, like that of a single summer.

The deep ice-channels in which the kames were accumulated seem to have been formed only at or near the mouths of the glacial rivers, not extending far from the melting edge of the ice-sheet. In this lower portion of the Merrimack valley, and elsewhere in eastern New Hampshire and Massachusetts, the retreat of the glacier seems to have been so rapid that extensions of these kames were often entirely deposited in a single year. The ice-walls by which they were enclosed melted back about as fast as the formation of the channels and kames advanced. Though separate portions of these kames were thus probably wholly deposited in a single year, their annual progress was small; and the formation of the entire series, extending 20 miles, occupied a long period.

The substitution of coarse angular materials, instead of the common water-worn gravel, seems to have taken place at times of very rapid melting, whenever such materials happened to be set free from the ice in large amount near the mouth of the glacial rivers. They were then swept by the violent current into the place of the ordinarily water-worn kames. At the most notable of these localities, which occurs in Hooksett (p. 88), a medial moraine, or a similar train of materials which had become enclosed within the ice, seems to have been thus undermined by the glacial river, and left to appear as a portion of this series.

It remains to add a few statements in regard to kames found farther southward in this valley. A fourth of a mile west from Reed's Ferry we noted irregular ridges of partly angular and partly water-worn materials, which enclose small ponds in their hollows. These kames appear to be isolated, not forming a portion of any series. After discontinuance for fourteen miles next below the long series which extends from Loudon to Manchester, we again find lines of kames in the main valley, upon both sides of the river and a mile apart, in Hudson and Nashua. They begin in Hudson, a short distance south-west of Otternic pond, and extend southward two miles. This series may be seen at the north side of the road leading east from Nashua bridge, near where the river road turns off to the south. It is traceable from this point a half mile northward, consisting of two or more crooked ridges 20 to 30 feet in height. This material is considerably water-worn, the largest pebbles seen being a foot and a half in diameter. Following the river road southward, we find but a single ridge, similar in height and material, but nearly straight, which lies for the first third of a mile on the east side of the road, and beyond on the west side, diverging from it towards the river. This ridge is 75 to 100 feet above the river, which is here 93 feet above the sea. The modified drift of the next half mile southward, extending to an exposure of the till, consists of a level gravel plain, 75 feet above the river, which contains pebbles up to one foot in diameter. This very coarse alluvium has a greater height than the finer deposits west of the river. It seems to be of earlier date than these plains, or even than the kames northward, and was probably formed in the same way with the latter, differing only in its greater extent.

In Nashua, excavations have been made in remnants of the kames on the north side of Canal street, and on the west side of the Nashua & Lowell Railroad, a quarter of a mile south from the Concord depot. A short series seems to extend from the latter point to the south-west, principally concealed by later deposits. A mile and a half farther south, near the city farm, we find another ridge which has been excavated for gravel at its north end. This extends south-easterly nearly continuous for a mile, and is from 20 to 40 feet high. The road lies parallel with it on its north-east side for four fifths of this distance, but at length turns to the south, crossing the kame and rising above the alluvial area, of which this ridge forms the border. The material of these ridges is water-worn but quite coarse, containing stones up to one and a half or two feet in diameter. These kames are probably to be regarded as portions of a series which was never connected. A mile southward it appears again, here also at the west margin of the alluvium, between the highway and railroad, south of Little's station. The highest of these kames in Nashua does not exceed 100 feet above the river. This series does not appear to extend into Massachusetts.

Several other deposits of this kind were noticed at the west and north-west within the limits of our map. Fairmount heights, a coarse gravel plain on the north side of Nashua river, west of the city, is a deposit of similar origin with the kames. Near the west line of Nashua, ridges and mounds of this gravel occur on the south-east side of this river. Other kames, forming very coarse gravel ridges, were observed in the north part of Hollis near a school-house and saw-mill, on the south side of Pennichuck brook; and in Amherst, a third of a mile south from the railroad station. Similar deposits, most frequently of small extent, may be found in almost every town in New Hampshire.

The description of the ordinary alluvial terraces and plains of the Merrimack was interrupted at the mouth of Soucook river. Thence nearly to Manchester the average width of the alluvial area is about one mile. Its narrowest place is at Hooksett, where ledgy hills rise close to the river on both sides. The Pinnacle, a sharp peak of white quartz on the west, 350 feet above the river, affords a very beautiful view of the valley north and south, including several villages. The most interesting portion of the alluvium is its highest terraces. These are from 100 to 125 feet above the river, and are usually well shown upon both sides. Their similarity in height on opposite sides and their very steep escarpments facing each other, as already frequently pointed out, indicate their formerly continuous extent. These upper terraces form wide plains in Bow, which have been partly eroded by Moore's brook, and in Hooksett, south of the Pinnacle and north from Martin's ferry. The last of these areas extends back at the north one mile from the river. The greater part of its material is coarse gravel, and its origin seems to have been from the north-east at the time of the departure of the ice, differing from the ordinary fine alluvium, which was slowly deposited from the floods of the main valley.

Valuable beds of clay, extensively used for brick-making, occur in the highest terrace for four miles north from Hooksett, upon the east side. This clay appears to form a nearly continuous stratum, which has a thickness of from 20 to 30 feet, with its top about 100 feet above the river. It is overlaid by a few feet of sand. The upper part of this stratum consists of a hard and compact *gray clay*. At a depth of 10 to 15 feet this is usually separated, by a thin layer of sand one fourth of an inch to three inches thick, from the underlying *blue clay*, which is soft and plastic when dug from the bank. A gradual transition from the gray to the blue clay is rarely seen. These divisions are nearly equal in amount, but in some of the brick-yards only the upper gray clay is exposed. Except the lower part of the blue clay, which is of inferior quality, both layers are well adapted for brick-making. Deposits of the same gray and blue clay, the latter always below the former, are frequently found in the south-east part of the state, near the coast, and along the Hudson river and Lake Champlain.* Two miles above the most northerly of these brick-yards, a similar stratum of clay about 25 feet thick, overlaid by 15 feet of sand, is worked near Bow Mills. A large alluvial area, including clay-beds, borders Suncook river from one to two miles above its mouth.

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* *Natural History of New York*, Mather's *Geology of the First District*, p. 128, etc., and Hitchcock's *Geology of Vermont*, pp. 157, 160, etc.

These deposits of clay were accumulated in very quiet water. The rivers which flowed from the melting ice-sheet appear to have brought down a greater depth of modified drift in the south part of Hooksett than was supplied along the distance in which the clay-beds occur. A considerable depth of nearly still water was thus held back in this part of the valley during the deposition of the extensive plains of Concord; and the same floods which deposited fine gravel and sand in Concord, carried forward clay to Pembroke and Hooksett. When this channel was nearly filled, and the river began to excavate the barrier below, the current became so rapid that a layer of sand was formed above the clay.

No very extensive tracts of interval are found on the Merrimack south of Concord. The low terrace, lying slightly above the freshets, but having nearly the fertility of an interval, sometimes occupies large areas; but its average extent is much less than that of the high terraces or plains, which often come nearly to the river. From the mouth of the Soucook river to Hooksett the low terrace is well developed on the west side, averaging a quarter of a mile wide. On the east side it is narrow, but attains considerable width between Suncook and Hooksett, where it is interval. Southward to Manchester it is nowhere wide, but nearly all the way occupies a narrow margin on each side of the river. The Concord Railroad, along its entire length, is built on this terrace.

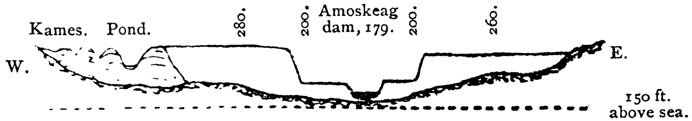


Fig. 21.—SECTION IN MANCHESTER. Length, 2 miles.

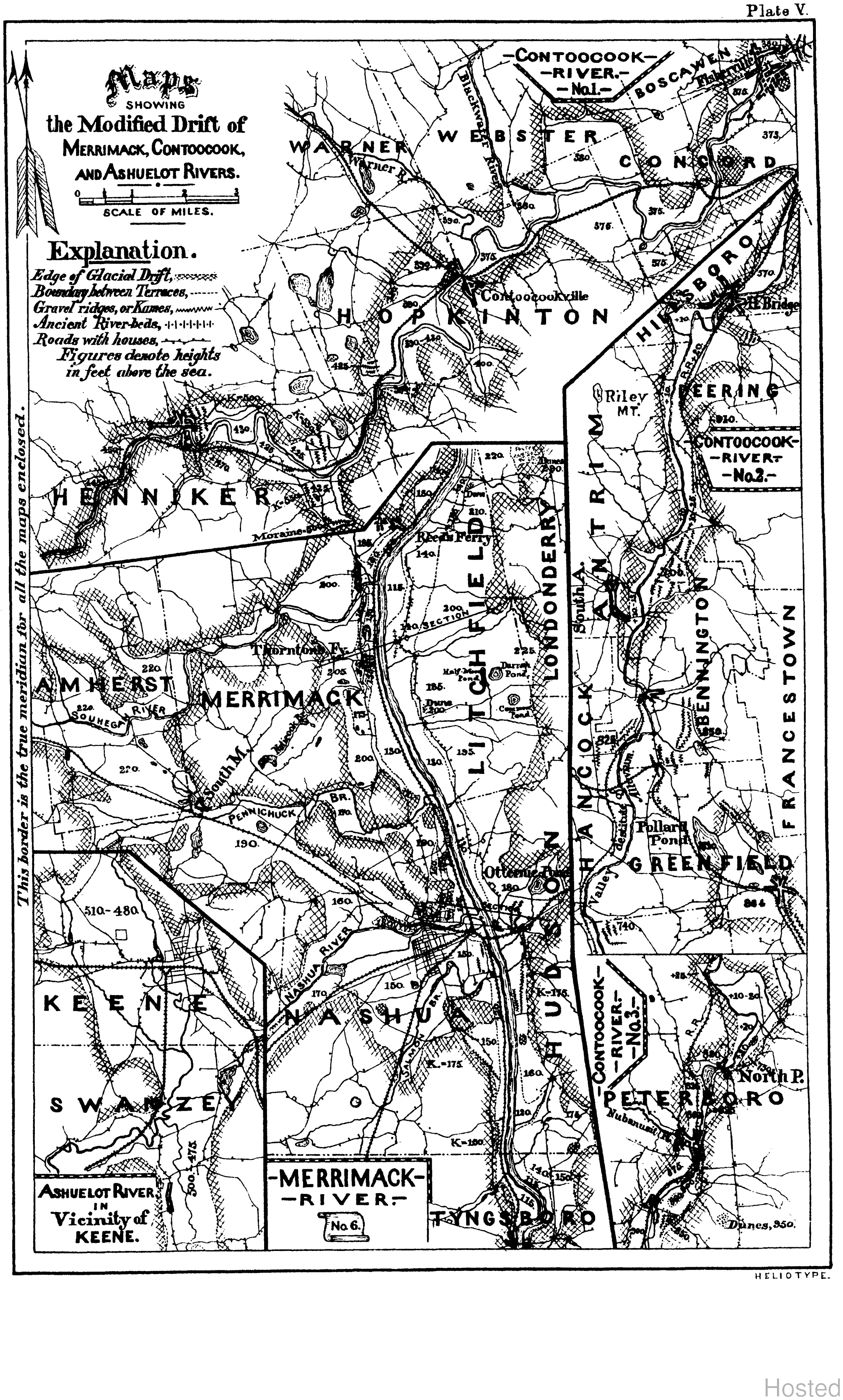
At Amoskeag falls the alluvium is two miles wide, and it averages thus for three miles, the city of Manchester lying at the middle of this distance on the east side. The largest part of this area consists of high sandy or gravelly plains, whose barrenness made this township, under its former name of Derryfield, proverbial for poverty. The Amoskeag falls were then utilized only as a fishing-place. The river here descends 56 feet, from 179 to 123 feet above the sea; and its water-power has within fifty years built up the largest city in the state. The plains on the west side are extensive, both north and south of Piscataquog river, descending from 280 to 265 feet above the sea. The upper edge of the alluvium in the north-east part of the city is from 260 to 265 feet above the sea. Elm street lies upon a terrace intermediate between the high plain and that of the depot. Wells upon this street show about 25 feet of common sand, in the lower part of which water is obtained by the shallower wells; then, 20 feet of quicksand, with no springs, beneath which is a thin layer of clay, lying on unmodified drift or till. The deeper wells find their springs between the clay and till.

Piscataquog village also lies mainly upon an intermediate terrace, which extends a mile to the south, being occupied by the river road. The lowest terrace appears between this and the river; farther south it attains a large width, and is crossed by the river road at Bowman's brook. The same terrace is also wide on the east side north of Goff's Falls.

About a mile south from the city of Manchester an extensive, ledgy hill, isolated in the alluvial area, lies between the Concord and the Manchester & Lawrence railroads. The plain below this barrier to Goff's Falls does not quite reach its normal height, being 210 feet above the sea, or 100 above the river at the mouth of Cohas brook. In the north-western part of Londonderry it is slightly higher, and large quantities of its sand have been blown to the south-east 75 feet above it into irregular mounds and ridges upon the hillsides. Southward, the high plains are continuous and wide to Hudson.

On the west side the plains are wanting most of the way for six miles from Bowman's brook in Bedford to Reed's Ferry. This side of the valley appears to have been specially subjected to the erosion of the river, which has in many portions removed nearly every trace of modified drift, leaving the till or ledge sloping to the present channel. The till is frequently exposed in the banks or bed of the river between Manchester and Nashua, and also sometimes appears on the surface of the extensive plains, showing that the modified drift has not so great a depth as in the widest portions of this valley northward. Nearly opposite Goff's Falls, and on Sebbins brook at the south line of Bedford, the alluvium expands, forming three terraces, the highest in each case being 90 feet above the river.

Plate V.



HELIOTYPE.

In Litchfield and Merrimack the high sandy plains have a larger development than in any other portion of this valley excepting Concord. On the east side we find the modified drift occupying almost the entire township of Litchfield. An area from one fourth to three fourths of a mile wide next to the river is the low fertile terrace,—which is partly interval, as opposite the mouth of Souhegan river, but mostly lies somewhat above high water. East of this is the plain, about 100 feet above the river, coinciding in its eastern boundary nearly with that of the township. Its greatest width is opposite Thornton's Ferry, where it extends three miles back from the river. Its surface is in general very level; a depression is partly occupied by Darrah, Halfmoon, and other ponds. This wide alluvial area becomes narrowed to two thirds of a mile after entering Hudson, but again expands about Otternic pond, which is surrounded by plains. Two miles farther south, below Nashua, this area is contracted to only one fourth of a mile at each side.

The plains of Merrimack extend five miles southward from Reed's Ferry, having the same height as on the east side, and extending back nearly two miles from the Merrimack at their widest portion, which is along Souhegan river to Burnap bridge. Below this the alluvial area averages a mile wide nearly to Pennichuck brook, on whose north side it is interrupted by till which extends almost to the river. More than half of this width is occupied by the plains, which are mostly very level, with scarcely any elevations above the general surface, but having occasional hollows that often enclose small ponds. A considerable portion of the plain at one mile south from Thornton's Ferry has undergone erosion to the amount of 25 feet, now remaining 75 feet above the river. At the south-west part of this terrace clay deposits, which have been used for brick-making, occur near two small ponds. A single low terrace, one third of a mile wide, lies between the southern extension of these plains and the river.

From Reed's to Thornton's Ferry, two terraces are well shown below the plains. The north part of Souhegan village, and the road farther south, lie upon the higher of these, which is about 60 feet above the river. A succession of five terraces was observed south of Naticook brook at Thornton's Ferry. The river here is 100 feet above the sea, and the terraces are 20, 35, 50, 75, and 105 feet above the river, the first being interval, and the last the high plain. They all extend southward beyond the village, except the second, which terminates a short distance south-west of the depot. The third represents the immediate terrace which we noted as commencing at Reed's Ferry. The lower terrace along this distance is now in large part above the reach of the annual floods; but its undulating surface, very noticeable along the railroad, shows that nearly every portion of its area has been at some time occupied by the constantly varying channel of the river. The crescent-shaped pond north of Naticook brook lies in an ancient river-bed; another ancient channel, considerably above that of the present day, is crossed shortly after turning off from the main road in Litchfield to go to Thornton's Ferry. At the east landing of this ferry the bottom of the bank is a thick stratum of clay, which is overlaid by sand.

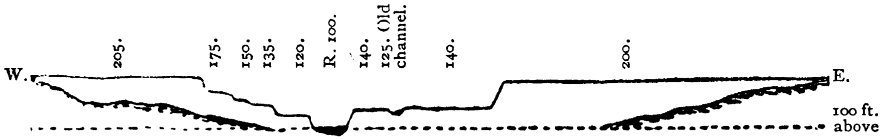


Fig. 22.—SECTION IN MERRIMACK AND LITCHFIELD THROUGH THORNTON'S FERRY. Length, 3½ miles.

Through Nashua we find the width of the alluvium narrowed, and till extending at several places almost to the river. An isolated area of till lies close to the railroad just south of Pennichuck brook. A former channel of this brook is plainly traceable here for a mile; it is crossed by the railroad a short distance south of the bridge, and thence extends southward, forming a long, nearly straight hollow in the terrace between the railroad and the river. A short distance farther south a succession of four terraces appears, at heights of 30, 55, 65, and 95 feet above the river. The highest of these forms a plain, over which the road next to the river extends for a mile south from Pennichuck brook. A small peat-bog lies in a depression on the west part of this plain. Two thirds of a mile north of Nashua river a narrow area of till extends almost to the Merrimack. Much of the till of this section is quite different from that usually seen, as it contains very few large boulders: its coarser portions are mainly pebbles and chips of rock, not often exceeding one foot in size. The former were derived from the neighboring Lake gneiss at the north, and the latter from the compact mica schist and quartzite of the Merrimack group. The kames of Nashua and Hudson differ in the same way in respect to their material from those farther north. South of the till mentioned three terraces occur. The middle one corresponds in height to the extensive plain of the south part of the city, which is 150 feet above the sea, or 57 feet above Merrimack river. This plain averages two miles in width for three miles west from the Merrimack, to Mine falls on Nashua river. It lies mostly on the south side of this river, and also includes the last three miles of Salmon brook within its area. The water-power of Nashua is supplied by these streams, the utilized fall of Nashua river being 51 feet, and that of Salmon brook 57 feet.

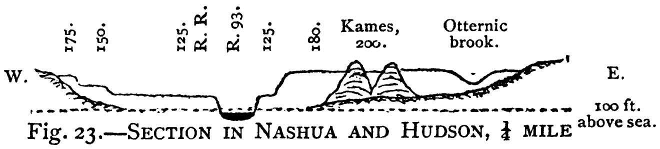


Fig. 23.—SECTION IN NASHUA AND HUDSON, ¼ MILE NORTH FROM THE MOUTH OF NASHUA RIVER.
Length, 2 miles.

The origin of the material of this plain was partly from each of these streams and partly from the north-west, along the avenue followed by the Wilton Railroad. Salmon brook has considerable alluvial deposits along its whole course. Very interesting kames occur along this brook in Dunstable and in Groton, Mass. They extend several miles, lying north and south, and are well seen from the Nashua, Acton & Boston Railroad. It appears that these were formed when this was one of the principal outlets from the melting ice-sheet. After the full disappearance of the ice the direction of drainage was changed, and a part of the deposits of this area has been carried back northward by this brook.

Main street in Nashua, at the city hall and at the Worcester depot, has the same height with the dam at Mine falls (152 feet above the sea). The descent of the plain eastward in this distance is about 20 feet. Three miles farther south-west, upon the Nashua river in Hollis, we find plains 50 feet higher, or 70 feet above the river, which has a wide alluvial area on both sides to Massachusetts line. Kames, which were probably formed by waters flowing south from the melting ice, occur in Nashua just north of Hollis station, and on the east side of the railroad at the next crossing to the north; and others, previously mentioned, lie near the river, a mile farther north. One of the finest displays of kames to be

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found in Massachusetts is shown near the head of Nashua river, along the railroad between Fitchburg and South Ashburnham. These kames lie in north-west to south-east ridges parallel with the valley. When they were being formed we must suppose that the ice had gone from the lower east and north-east portions of the river's course, and that the floods of water supplied from the melting ice-sheet at its source were then completing the deposition of these extensive plains at its mouth.

At the same time floods were here poured into the Merrimack from the north-west, where no stream now exists. A continuous belt of alluvium, upon which the Wilton Railroad is built, extends six miles from the Souhegan river in Amherst to the plains of the Nashua river. Its narrowest place, three miles from the city, is a third of a mile wide, while its widest portions, in the north-west corner of Nashua and south part of Amherst, are a mile and a half wide. These plains show a gradual descent from north-west to south-east, amounting to 75 feet in the six miles. They consist of levelly stratified sand and gravel, and in general have a very regular surface; but several ponds, often with no outlets, fill depressions upon their widest portions, as Stearns pond in Amherst, Pennichuck pond near South Merrimack, and Round pond in Nashua. Deposition probably took place very rapidly from floods which brought down the material from the melting ice-sheet. In some cases masses of ice may have remained where we now find these ponds, or they may be due to an unequal supply of material and varying currents. The waters of the Souhegan valley at this period found their way to the Merrimack by three routes. One was along the present course of this river, which, below its extensive plains in Amherst, is narrowly enclosed at two points by high land of till or ledges; a second, similar to the first, was along Pennichuck brook; while the third, which differs from the others in its ample width and direct course, brought the greater part of these floods to the same mouth with the Nashua river. In this way the flood-plains of the last route appear to have become slightly higher than along the present Souhegan river and Pennichuck brook, which therefore became the channels of drainage after the Champlain period.

A half mile below the mouth of Salmon brook, hills approach nearly to the river, beyond which is a plain of similar height with that south of Nashua river. In the remaining three miles to Tyngsborough the allu-

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vial area on the west is narrow, consisting principally of the low terrace, which is about 25 feet above the river. Plains of considerable extent occur on the opposite side, 50 to 75 feet above the river. At Tyngsborough the alluvium is wholly cut off on the west, and nearly so on the east, by hills of ledge or till.

Five miles south of the state line, the Merrimack river turns to the east at North Chelmsford, and thence pursues a devious east and north-east course, at right angles to its valley in New Hampshire, about thirty-five miles to its mouth three miles east of Newburyport. South and south-east from its bend are extensive low alluvial plains. These were deposited by the floods from the melting ice-sheet in New Hampshire, which kept their course south-east to Massachusetts bay. These plains form the very low water-shed between Lowell and Boston, and are the continuation of the slowly descending ancient flood-plain, which we have traced in the upper terraces of Merrimack river through New Hampshire. When these extraordinary floods abated, the river found a lower channel, which had been mainly sheltered from the deposition of modified drift by its crookedness and closely bordering hills.

The area here crossed by the river is remarkable for peculiar accumulations of till, which forms steep, smoothly rounded oblong hills 100 to 200 feet in height. These are set almost as thickly as possible over an otherwise nearly level country. Their prevailing trend, especially north of the Merrimack, as in South Hampton and Kensington, is north-west to south-east, or approximately parallel to the motion of the ice-sheet, which must have heaped them up beneath its mass, and left them at its melting in their present form. The next chapter will contain a full description of these hills, which occur occasionally in many portions of New Hampshire.

At the mouth of Merrimack river a ridge of sand, 25 to 50 feet high and 10 to 40 rods wide, extends several miles both to north and south, facing the ocean. Its gentle east slope forms the beaches of Salisbury and Plum island. This portion of the sand brought down by the river has been swept back again by the waves, and lifted above their reach by the wind. Marshes a mile wide lie on the west side of this ridge. These recent deposits will be described, with those of the coast northward, in a later portion of this chapter.

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RECAPITULATION OF MODIFIED DRIFT OF PEMIGEWASSET AND MERRIMACK RIVER.

PLACES.	Distances in miles from Profile lake.		HEIGHTS IN FEET ABOVE THE SEA.	
	Direct course (valley).	Course by the river.	River.	Highest terraces.
Mouth of East Branch,	9.2	9.3	710	780, E. 770, W.
Woodstock, ...	12.5	12.7	627	735
West Thornton, . . .	15.5	15.8	576	685, E. 690, W.
2 miles south, ...	17.5	17.8	565	655, E. 660, W.
4 " "	19.5	19.8	555	630. Kames. 650–670.
West Campton, . . .	21.7	22.1	540	590, E. 630, W.
3 miles south, ...	24.7	25.1	520	620, E. 600, W.
Livermore falls, . . .	26.3	26.8	505–483	600, E.
Plymouth, ...	28.2	28.8	468	555–570, E.
South line of Plymouth,	31	32.5	463	560, E. 525, W.
Ashland, ...	33	34.5	459	565
2 miles south, ...	35	36.5	450	525, E. 540, W. Dunes, 825, E.
New Hampton, . . .	39	41	438	510
Bristol, ...	42.8	45.2	352	502, N. 435, E.
Mouth of Smith's river,	44.8	47.5	320	460, W.
Hill, ...	48	51	305	480, E. 410, W.
Mouth of Salmon br'k,	51.5	54.7	300	475–465, E. 415, W.
Franklin, ...	54.6	58	295–269	440–420, E. 445–430, W.
Webster place, . . .	57	60.7	260	430–550, E. 430, N. W. Dunes, 700, E.
North Boscawen, . .	60	64	256	385, E. 390, W.
Boscawen, ...	63.5	68.4	252	370–360, E. 340–310, W.
Fisherville, ...	66	71.5	249	340–320, E. 380–373, W.
West Concord, . . .	69.5	75.5	229	355–350
Concord, ...	72	79.5	227	350, E. 367, W.

Altitudes for reference, and remarks.

No prominent *tributary deltas* occur in this valley.

Profile lake, about 1950.
Woodstock town-house, 734; bridge, 649.
West Thornton bridge, 596.
Livermore Falls bridge, 561; dam, 511.
Plymouth railroad station, 490.
Ashland station, 562.
New Hampton bridge (centre), 462.
Bristol station, 369; Main St. bridge, 469.
Newfound lake, 590.
Railroad bridge, Smith's river, 336.
Hill station, 335; bridge, 331.
Franklin sta,, 363.26; bridge (centre), 304.
Junc. of N. R. R. and Bristol Branch, 364.
Webster Place station, 295.
North Boscawen station, 290.
Boscawen station, 274.
Fisherville, railroad bridge, 268.
W. Concord sta., 353; E. Concord sta., 246.
Concord station, 252.39; state house, 292.
Datum for city levels (called 0), 225.29.
Top of city water-works dam, 412.
Railroad bridge, Merrimack river, 247.
" " Soucook river, 221.
" " Suncook river, 243.
Hooksett sta., 206; R. R. bridge south, 205.
Martin's Ferry station, 199.
Amoskeag Falls dam, 179; flash-boards, 181.
Manchester station, 180.83.
Datum for city levels (called 0), 108.98.
Massabesic lake, 256.
Manchester & No. Weare R. R. bridge, 169.
Goff's Falls station and bridge, 146.
Reed's Ferry station, 137.
Railroad bridge, Souhegan river, 128.
Thornton's Ferry station, 125.
Railroad bridge, Pennichuck brook, 127.
Nashua station, Concord Railroad, 123.
Datum for city levels (called 0), 93.10.
Reservoir of water-works, 247.
Nashua & Rochester Railroad bridge, 126.
Pawtucket Falls dam, Lowell, 87.
Essex Company's dam, Lawrence, 39.

This river is affected by tide to Mitchell's falls, 2½ miles above Haverhill, Mass.

Along Contoocook River.

Mouth of river, Fisherville, 249.
Borough dam, about 355.
Mast Yard station, 374.
Contoocook station, 373.
River above do., about 365.
West Hopkinton station, 392.
Henniker station, 439.
River below Henniker, 389.
Foot of Long fall, 433; head of do., 546.
Hillsborough Bridge station, 574.
Foot and head of falls in the river at Hillsborough Bridge, 564–591.
at Bennington, 606–676.
" North Peterborough, 714–724.
" Peterborough, 727–734.
Peterborough station, 744.
River at county line, about 875.
East Jaffrey station, 1032.
3 ponds in north part of Rindge, each 1114.

PLACES.	Distances in miles from Profile lake.		HEIGHTS IN FEET ABOVE THE SEA.	
	Direct course (valley).	Course by the river.	River.	Highest terraces.
Mouth of Soucook river,	76 3	85.3	199	300, E. 330, W.
Suncook, ...	78.6	88	198	305–315, E. 325, W.
Hooksett, ...	80.6	90	197–181	315–290, E. 325, W.
Martin's Ferry, . . .	84.3	94	180	312–298, E. 295, W.
2 miles south, ...	86.3	96	180	280, E. 290, W.
Manchester, ...	89	99	179–123	265–260, E. 280–265, W.
Goff's Falls, ...	92.5	102.6	119–110	210, E. 205, W.
Reed's Ferry, ...	96.5	106.8	104	210, E. 185–200, W.
Thornton's Ferry, . .	98.7	109.2	100	200, E. 205, W.
Mouth of Pennichuck br.,	101.3	112	96	190
Nashua, ...	104	114.7	93	180–170
State line, ...	108.3	119	90	175–150

Altitudes for reference, and remarks.

In the Lake District. *

Mouth of Winnipiseogee river, 269.
Cross's mill-pond (Win. river), 415.
Tilton station, 458; Winnipiseogee Company's pond (Win. river), 450.
East Tilton station, 499; Little bay, 473.
Sanbornton and Great bays, 490.
Round bay, Laconia, 501.
Winnipiseogee lake (high water), 513.
Meredith Village station, 556.
Wukawan lake and Long pond, 549.
New Hampton station 578.
R. R. summit 2 ms. S. E. from Ashland, 679.
Squam and Little Squam lakes, 569.

Slope of the highest terrace in Merrimack Valley.

	Miles.	Ft. per mile.
From mouth of East Branch to south part of Thornton, .	10	15
" Livermore falls, . . .	7	4
" Plymouth, ...	2	15
" Ashland, ...	5	0
" Mouth of Smith's river, .	12	9
" " Salmon brook,	6½	0
" North Boscawen, . . .	8½	9
" Hooksett, ...	20½	3
" Manchester, ...	8½	7
" Goff's Falls, ...	3½	15
" Thornton's Ferry, . . .	6	2
" State line, ...	9½	4
Total distance, . . .	99	6.2

Modified Drift along Contoocook River.

The modified drift of Contoocook river, mapped on Plate V (p. 96), has been explored for a distance of forty miles from the east line of Jaffrey to its mouth. This is the largest tributary in the state. It gives the best example found within our limits of a long valley descending from south to north. The upper twenty-five miles of the distance explored has a quite straight course a few degrees east of north. At Henniker the river turns eastward, and thence flows slightly east of north-east fifteen miles to its junction with the Merrimack at Fisherville. These distances measure the direct course of the valley, not the meandering channel of the river, which exceeds fifty miles.

From the northward course of this valley, we should suppose that the

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* These heights were determined by levelling from Franklin station by Winnipiseogee lake to Ashland, and thence along Pemigewasset river to the point of beginning. By this complete circuit they were proved to be correct, as compared with the altitudes given in Vol. I, p. 258, and also here, for Franklin and Concord.

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conditions which prevailed at the melting of the ice, and the modified drift then deposited, would differ from the common type. This expectation was fully justified by exploration for thirty miles, along which distance deposits were found different from any seen elsewhere in the state, together with frequent kames; and it is only after entering Hopkinton, and along the last ten miles of the river, that it is bordered by the ordinary level and continuous alluvial plains.

We will first describe the modified drift of this valley in order, proceeding from its source to its mouth, without intruding any theories; after which, we will seek an explanation of the facts observed. Several ponds in the north part of Rindge constitute the head waters of Contoocook river; and others in the same town are among the principal sources of Miller's river. The water-shed on which these ponds lie is a comparatively level plateau, partly covered by large amounts of coarse, water-worn gravel, and elevated 1,100 to 1,200 feet above the sea.

At the line between Jaffrey and Peterborough, where our special examination of the valley began, the river is about 875 feet above the sea. For the first mile the stream is bordered by coarse, water-worn gravel, containing pebbles one to two feet in diameter, interstratified in nearly equal proportion with sand. These deposits occur in ridges or irregular terraces, which reach a height of 150 feet above the river. They are well exposed by the excavations for the railroad, along which they extend, decreasing in height at the north, to within a half mile of Noone's mill. Thence northward to Peterborough village the principal deposits on the west side are sand, which slopes very irregularly from the river to the height of 100 feet at the distance of a quarter of a mile on the hillside. This was seen in some places to be stratified conformably to the surface, and it is scarcely anywhere distinctly terraced so as to show steep escarpments with a wide, level top. Boulders of various sizes, up to four or five feet in diameter, are frequently found embedded in this stratified sand.

South-east from Noone's mill we find an interesting assemblage of kames, in irregular ridges, which rise from 50 to 75 feet above the river. These are three or four in number, lying approximately north and south and parallel to each other. Their material is water-worn gravel, containing pebbles up to a foot and a half in diameter. At one point a ridge turns abruptly from a northward to an eastward course, enclosing a pond in the triangular hollow between it and the adjoining ridge. A short distance to the north is a hill, about 90 feet above the river, which appears to consist of till overlaid by a gravel deposit. This is surrounded by low alluvium. A little farther north the river flows at the eastern foot of a gravel ridge, which is about 40 feet in height. A boulder six feet in diameter was noticed in this ridge; but such blocks are very rare in these kames, and were nowhere seen in the high gravel deposits farther south.

One mile east from Noone's mill, sand dunes occur on the hillside at a height of about 200 feet above the river, covering some two acres, which are almost destitute of vegetation.

The Contoocook, at the mouth of Nubanusit river in Peterborough village, is 734 feet above the sea. Here till and ledge rise steeply on the east side, which has no modified drift. Half a mile to the north a considerable width on this side is occupied by alluvial sand and fine gravel, which extend in irregular slopes to 100 feet above the river, rarely showing any steeply-terraced or level-topped surface. The most irregular portion of this area is at the cemetery, which is diversified by kame-like mounds and ridges. As we approach North Peterborough the till and ledge again reach to the river. Along this distance on the west side, similar sand and gravel, in irregular slopes, thinly cover the hills to a height of 100 to 150 feet above the river. Occasional boulders are found enclosed in these deposits.

At North Peterborough a broad, terrace-like ridge of sand extends half a mile on the north-west side of the river. This has steep slopes, but its top is nearly level, with a height about 100 feet above the river, being at the south 820 and at the north 810 feet above the sea. The valley here bends for a short distance to the east, so that to one following the river northward this ridge at first appears to lie as a barrier before it. With this huge sand-bank the high deposits of modified drift, which we have found bordering this river continuously for five miles, come to a sudden end.

Half a mile eastward a small terrace, about 50 feet above the river, lies on its east side. Excepting this, we find in the next two miles only low alluvium, which averages a half mile in width, lying mostly on the east side of the river, with a height of 10 to 30 feet above it. Beyond this we find the valley for the next six miles, extending nearly to Antrim, well-nigh destitute of any alluvial or terraced deposits; yet it has along most of the way an ample width with gently sloping sides, which are usually the conditions for the accumulation of extensive plains. In this distance, and for several miles farther north, the descent of the river is small, amounting to 123 feet in the sixteen miles between North Peterborough and Hillsborough Bridge. More than half of this occurs at Bennington, where its fall is from 676 to 606 feet above the sea; for the rest, the average slope is about three feet to a mile.

The only important deposits of modified drift seen along this river for six miles were kames, which appear on the east side near the north line of Peterborough, and are very well shown upon both sides of the valley at one mile south-east and south-west from Bennington. In the north edge of Peterborough these consist of sand or fine gravel, which lie in numerous mounds and ridges, in depths to 20 or 30 feet, upon a sloping hillside of till 90 to 100 feet above the river. These deposits are irregularly stratified, conformably in some places, and perhaps generally, to the underlying surface. They contain here and there embedded boulders, the largest of which observed was four feet in diameter.

From a half mile to more than a mile south of Bennington, on both sides, we have large accumulations of kames. On the west they rise to about 140 feet above the river, and consist of sand in hillocks and north and south ridges, which are 50 to 75 feet in height, lying on till. In the sand, which is irregularly stratified as seen in many places, there also occur occasional boulders up to four feet in size. On the east side these ridges and banks are well shown along the road to Greenfield before coming to Whittemore pond. They are composed in large part of the coarse, water-worn gravel which is characteristic of the kames, interstratified with sand, and containing embedded boulders. These deposits reach a height fully 175 feet above the river, or 850 feet above the sea. Thence to the south-west similar deposits border the north and west sides of the hills to within a half mile of Pollard pond, being well shown on the east side of the Manchester & Keene Railroad, now being built, for one mile south from Bennington station. Here they form nearly level terrace-like banks of fine gravel or sand, 170 to 175 feet above the river, irregularly stratified and rarely containing boulders.

At Bennington station the kames are very well displayed, forming long and narrow steep ridges. One of these has been here cut through for the railroad, and shows very instructive sections. Its base is 40 feet above the river, and its height about 20 feet. Fig. 24 shows the simple transverse section at the south side of the cut; and Fig. 25 shows the section on the north side. The east portion of the last is directly transverse, but its west portion is a longitudinal section, extending farther north.

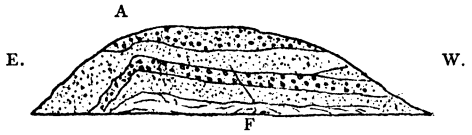

Fig. 24.—South side.

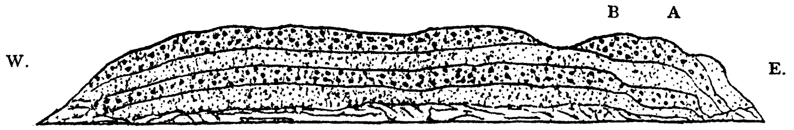

Fig. 25.—North side.
Sections of a Kame, Bennington Station, M. & K. R. R.
Scale, 25 feet to an inch.

This kame showed the following succession of deposits, beginning at the top:

1. Coarse yellow gravel, containing pebbles up to 8 inches in diameter;—thickness, 3 to 5 feet.

2. Fine sand, whitish and yellowish;—thickness, 3 to 5 feet.

3. Coarse dark gravel, containing pebbles up to one foot in diameter;—thickness, 3 feet.

4. Sand, same as No. 2, obscured at bottom by crumbling of the bank;—thickness, 4, perhaps 8, feet.

A–A. Downfall of strata, with irregular, broken steep slope, against which lies an accumulation of sand.

B. Depression of 2 feet, similar to the foregoing (not extending to south side).

F. Fault, seen only on south side;—dislocation of strata, 6 inches.

Boulders up to seven feet in diameter are rarely found on the top of this kame; but none were observed embedded in it. It will be noticed that the alternate layers of gravel and sand preserve a nearly uniform thickness throughout the excavation. It should be added that the gravel usually contains no clear sand and the sand no gravel; and that these succeed each other by a sudden change, not by gradual transition. These sections appear to show the deposition of two years, the coarse gravel being brought from the melting ice-sheet by strong summer floods, and the sand being deposited in autumn and spring. The line of downfall, A–A, appears to show where these materials at first rested against a wall of ice. When this melted, the strata suddenly fell as seen at these points.

In Hancock, a mile and a half farther west, the first excavation for this railroad after crossing the highway shows sand and fine gravel underlying till upon both sides of the cut. (Fig. 26.) This is on the south slope of a hill, at a height for the bottom of the cut of 28 feet above the river. The surface all around is composed of till and covered with boulders. The separation between the modified drift and till is not a definite line; but there is a gradual transition, occupying one or two feet, and the till has thin streaks of sand. No boulders were seen in the underlying deposit.

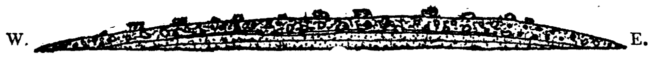

Fig. 26.—SECTION OF MODIFIED DRIFT UNDER TILL, HANCOCK.
Length of Section, 300 feet; height, 15 feet.

1. The unmodified drift, or till, contains boulders of all sizes up to 8 or 10 feet; its thickness is from 6 to 10 feet.

2. The modified drift is stratified in layers of varying thickness; sometimes contorted, but mainly horizontal; consisting of sand (in strata from 2 to 5 feet thick) and fine gravel (with the largest pebbles 3 inches in diameter); thickness exposed, from 5 to 7 feet, also extending below the excavation.

The lack of alluvial deposits in the Contoocook valley is made up where we might least expect it, two miles farther east, at a height of nearly 200 feet above the river, and not in the pathway of any large stream. Following the stage road from Bennington to Greenfield, numerous kames were seen north-east from Pollard pond, principally forming north-west to south-east ridges, and composed of coarse gravel. The road next enters on a nearly level plain of sand and gravel, which extends about two miles to the south, being from one half mile to one mile wide. Its height is from 850 to 870 feet above the sea. Hogback and Bridge ponds lie in depressions of this plain, with steeply sloping shores from 25 to 30 feet high. Pollard pond lies about 50 feet below the plain, of which with its outlet it forms the western boundary.

The first of these ponds has its name from gravel ridges or kames. These are well shown between this and Pollard pond, extending in north-west to south-east ridges, not higher than the plain, but shown as ridges because of intervening hollows. These kames, with most of the plain northward, consist of coarse, rounded gravel, with the largest pebbles from a foot to a foot and a half in diameter. Southward, sand predominates, but much kame-like gravel is also found. These materials are spread out comparatively level, but the excavation for the railroad shows that they have usually an oblique stratification, dipping mostly to the south-east. Greenfield village lies at the east edge of this alluvial area, which extends with its full width a half mile farther south. In this distance we find, on the east side of the railroad, kames containing pebbles up to a foot and a half in diameter, and lying in north and south ridges 20 to 30 feet higher than the plain. These continue along the railroad fully a mile to Cragin pond, forming a narrow belt, which is bordered by hills of ledge or till. Their southern portion is mainly of sand or fine gravel, and they terminate in a sand plain, which lies on the east side of this pond, 25 feet above it.

A water-shed scarcely higher than this plain and lower than the kames, being 863 feet above the sea, separates Cragin pond from the head-stream of Stony brook, which the railroad follows to Wilton, descending more than 500 feet in nine miles. The modified drift of this valley consists of occasional terraces and kames, but presents no remarkable features, and is scanty in amount.

No streams now exist, or can have existed with the present system of drainage, capable of forming the large alluvial plain of Greenfield. Excepting north of Pollard pond, the hills which lie between it and the Contoocook do not exceed the plain in height. Its extent along the outlet of Pollard pond is to the north-east corner of Peterborough, below which for two miles this stream is destitute of alluvium, as are also the low hills and even the valley of the Contoocook on the west.

At Bennington the valley is closely bordered by hills, beyond which we again find the modified drift continuous to Hillsborough Bridge, a distance of nine miles. The Hillsborough & Peterborough Railroad, now being built, is here on the east side of the river, and from South Antrim northward lies on a low and partly swampy plain 15 to 20 feet in height and a fourth to a half mile wide. The old muster-ground of "Cork plain," in Deering, is a part of this long terrace. On the west side the river has a similar but narrower alluvial margin, principally of meadow or interval, not exceeding 10 to 15 feet in height. At the north line of Antrim and Deering these deposits have their widest development upon both sides, covering a mile square.

Kames extend along the east side of this low alluvium from opposite South Antrim to the north line of Bennington. They are disposed in numerous mounds and ridges, which lie mostly north and south, attaining a height of 100 feet above the river, and occupying a third of a mile in width. Their material is sandy gravel, with the largest pebbles about one foot in diameter, but they contain, also, occasional angular boulders of sizes up to five or six feet. Near their north end the surface of ordinary till between these gravel ridges is strewn with massive boulders often ten feet in diameter. Kames are also found a half mile south-east from Hillsborough Bridge, in mounds 10 to 30 feet high.

A very remarkable accumulation of sand and gravel is found on the east side of this valley in Deering, two and a half miles south from Hillsborough Bridge, at a height of more than 300 feet above the river. On its north-west side an abrupt spur of Hedgehog hill, probably 450 feet above the river, projects half-way across the valley; and the same range rises still higher on the south-east. The deposit lies upon the south-west slope of the intervening hollow, reaching to the height of land which separates the hills. It consists of sharp-grained sand, interstratified with gravel, which contains pebbles up to six inches or nearly one foot in diameter. Four or five acres at the top are nearly level, and thence a long slope extends down nearly to the alluvial plain. The stratification of this sand and gravel is seen in gullies formed by rains or very small springs, which are making slow inroads upon the level area at the top, where the undisturbed strata are exposed, dipping to the south-west nearly at the same angle with the slope of the hill. No boulders were observed, either embedded or on the surface. This is the only high deposit of modified drift close to the river in this portion of its valley, and must be of different origin from our ordinary high terraces and plains; nor does any water-course exist by which it could be brought here.

Other notable deposits of sand and gravel, to be hereafter described, occur at nearly the same level on both sides of this valley through Hillsborough county. They are usually two or three miles distant from the Contoocook river, but in most cases border some tributary stream.

At Hillsborough Bridge the river is enclosed on both sides for a short distance by slopes of till. Below this place the alluvium forms low plains between the railroad and the river. The fall of the Contoocook at Hillsborough Bridge is 27 feet, its height at the head of this fall being 591 feet above the sea. At the head of Long fall, near the line between Hillsborough and Henniker, it is 546 feet above the sea, and in the next two miles it descends 113 feet through a narrow valley destitute of modified drift.

In Henniker a small terrace 15 feet above the river is crossed by the railroad near the foot of Long fall. A wider terrace, 30 feet above the river, extends nearly a mile from the west village to the railroad bridge. These are both on the north-west side, and are the only deposits of modified drift west of the principal village. At the east side of this village an interesting assemblage of kames is found, consisting of water-worn gravel, with the largest pebbles one to two feet in diameter, in three or four north and south ridges, 20 to 50 feet in height, nearly parallel with each other. They cover an area two thirds of a mile long and half as wide, and rise to a height of 100 to 125 feet above the river, which below the village is 390 feet above the sea. It will be seen that these ridges lie at right angles with the course of the valley, extending nearly across it, and causing the river to flow around them in a southward bend. East from the kames the river flows through intervals or low plains, 15 to 40 feet in height, which extend, with an average width of two thirds of a mile, through the township.

Two and a half miles east from Henniker village we find on the north side of the river, south-west from Whittaker pond, another group of kames lying in north and south ridges across the valley like the preceding, and reaching a height of 100 to 150 feet above the river. The material of these ridges is in part the usual water-worn gravel, but in some portions it contains principally angular fragments of rock one to three feet in dimensions. Whittaker pond is bordered on the south by a nearly level deposit of coarse rounded gravel, about 75 feet above the river.

Half a mile south-west from these ridges, on the south side of the river, we find a remarkable kame, half a mile long, with a course a little to the east of south, composed of sandy gravel, with pebbles frequently six to eight inches, but not commonly exceeding one foot in diameter. This forms a steep ridge about 100 feet above the hollow which separates it from a high hill an eighth of a mile west, and 125 feet above the low alluvium, which extends two thirds of a mile wide on the east. A small pond lies in this alluvium at the foot of the kame. The next third of a mile south shows no ridge, but it is succeeded by a very interesting moraine, which forms a steep and narrow crescent-shaped ridge, fully half a mile long, lying in a similar position with the kame between the hills and the low alluvial area. Its course is to the south-east and east, with height descending from about 75 to less than 50 feet above the alluvium, and it is separated from the hills by a hollow nearly as deep. The crest of this moraine consists almost entirely of angular boulders of all sizes up to ten feet in diameter, which cover the surface and are piled as thickly as possible, with scarcely any space for finer material. On the sides, and along the top near the east end of the ridge, we find earth and boulders intermixed in the ordinary proportions of the coarse upper till. These blocks are principally of two kinds, derived from the Lake and porphyritic gneiss, which occupy the whole country for more than ten miles to the north. The New Hampshire Central Railroad, now discontinued, was built in the hollow on the south-west side of both kame and moraine.

A noticeable feature of the Contoocook basin is, that its east and south-east water-shed is formed by high, irregular hills near the river, which has no large tributaries from this side. The lowest points of this water-shed usually exceed 400 feet above the river; but one or two miles south-east from this moraine the railroad found a line of depression only 150 feet above the river, or 537 feet above the sea. On each side high hills border this pass, which connects the Contoocook valley with that of the north branch of the Piscataquog river. No extensive or remarkable deposits of modified drift were seen in a hasty journey along the latter valley.

A third of a mile above West Hopkinton the Contoocook river flows between slopes of till 75 feet in height, and so steep as to suggest that the channel here may have been formed by the erosion of the river. A third of a mile from this railroad station, several parallel kames are found extending nearly east and west between the highway and the outlet from Rolfe's pond. These are composed of the usual water-worn gravel, with pebbles up to one foot in size, and form ridges and mounds 25 or 30 feet high and 60 feet above the river.

In the remaining ten miles of its course the Contoocook is almost continuously bordered by extensive low plains, seldom exceeding 30 feet above the river, with occasional areas of interval, but no kames were seen. On the south side of the river, below West Hopkinton, portions of these plains are 50 feet above the river; and on the north side the same height is reached by a delta-like deposit where the outlet from Clement pond enters the alluvial area. At Contoocookville the alluvium is interrupted by low areas of till or ledge, that upon the north side being quite low and scarcely higher than the plains, which seem at the edge of the village to extend across it. Thence eastward low sandy plains, from 15 to 25 feet above the Contoocook, extend nearly level for eight miles to the Merrimack river. Their greatest expanse is in the north-east part of Hopkinton, the north-west corner of Concord, and the south edge of Webster, where they cover an area three miles long from north to south and nearly two miles wide. This at the north consists partly of swampy land, slightly depressed, and with no outlet for drainage. Warner and Blackwater rivers, which are tributary to the Contoocook in Hopkinton, are bordered by considerable alluvial deposits, the former in Warner and the latter in Salisbury.

Three miles above its mouth the Contoocook is enclosed by hills with only a narrow alluvial margin. The proper continuity of its plain is here along the Concord & Claremont Railroad, with a hill between it and the river, east of which the plain is wide, lying principally on the south side of the Contoocook river, at a height of 125 feet above the Merrimack. Below Contoocookville the river has a height of about 355 feet above the sea nearly to Fisherville, where it descends rapidly to its mouth, which is 249 feet above the sea.

We will next consider the course of events in the Champlain period, of which these deposits of modified drift bear witness.

Review and Conclusions.

The continuousness in height of the plains of the Merrimack valley in Concord with those through which the last ten miles of the Contoocook flows, has been already noticed (p. 80). A comparison of this with the deficient height of the terraces of the Merrimack opposite to and for a few miles above the mouth of this river (pp. 78 and 79), leads to the conclusion that a large proportion of the modified drift of Concord was brought into the Merrimack valley by the Soucook and Contoocook rivers. The latter contributed to the plain of East Concord, and alone filled the large area between West Concord and Fisherville.

The extensive plains of the Contoocook, in the north-west part of Concord and through Hopkinton, occupy two basins of unequal size, which we must suppose held lakes at the first retreat of the ice-sheet. These were filled, as the melting of the ice continued, by the alluvium of its floods. A large share was supplied by the tributaries from the north; and the kames near West Hopkinton were formed by a glacial river, which descended at the head of the valley. To this point the formation of modified drift seems to have proceeded quite in the ordinary way.

In the east part of Henniker the first outlet from this valley was probably to the south-east into the basin of Piscataquog river. The moraine and kame which extend along the old line of the New Hampshire Central Railroad, at the south-west side of the alluvial area of the Contoocook, indicate a considerable period in which the terminal front of the rock-bearing glacier remained nearly stationary, succeeded by a period of retreat northward, when a large river, laden with sand and gravel, descended from the melting ice-fields. At the time of formation of this kame a small lake, nearly as deep as to cover its top, lay between the front of the glacier and the outlet of its waters to the south. The glacial river, entering this deep and quiet lakelet, deposited more quickly than usual nearly its whole freight, both of gravel and sand. Somewhat later, but while the outlet was still to the south, the kames on the north side of the valley south-west from Whittaker pond were formed; and we may presume that this date was nearly the same with that of the kames of West Hopkinton, which show that the valley of the Contoocook below was clear from ice. Not long after this time the glacial barrier between these basins disappeared, and drainage took its present course. Whether the kames at the east side of Henniker village were formed before or after this change, cannot perhaps be determined. Their position, transverse to the Contoocook, shows that they were formed by streams from the melting glacier on the north in the valleys of Amy and Warner brooks, while the rapid retreat of the ice to the west and south-west appears to have been delayed by the high hills which closely border the river. It is not improbable that, when these waters first flowed towards the north-east down the Contoocook valley, a barrier of till near West Hopkinton, afterwards eroded by the river, held back a shallow lake which extended to the kames last mentioned. The deposition of the low alluvium of this area was going slowly forward during all the time occupied by this history.

The melting of the vast ice-sheet over New England proceeded from the coast to the north-west and north, so that lakes were temporarily formed in valleys which drain northward. The avenues by which the waters escaped from the upper portion of the Contoocook basin, or that part above Long fall in the west part of Henniker, appear to have been three in number, as follows: Southward, over the water-shed at the head of the valley in Rindge; towards the south-east, through Greenfield; and northward, along the course of the river. The length of this area is nearly thirty miles; and the outlet in Greenfield is about equally distant from its south and north ends.

The conspicuous kames, which extend five miles along the Vermont & Massachusetts Railroad between South Ashburnham Junction and Westminster, show that a large area of the ice-fields on the north-west poured their waters along this course. These kames are less than 200 feet below the plateau in Rindge, twelve miles distant, which forms the water-shed at the head of the Contoocook valley. Although the present drainage of the south part of Rindge and of Winchendon is into Miller's river and the Connecticut, there is no considerable depression; and the separation between this basin and the head of the Nashua valley, in which these kames are found, is not so high as the water-shed in Rindge. This area has not been explored; but the deposits of modified drift in Rindge make it probable that the melting of the ice-sheet, while its outlet continued in this direction, proceeded beyond this divide, including a portion of the Contoocook basin.

The principal outlet from the part of this basin in Hillsborough county appears to have been through Greenfield south-easterly to Souhegan river. South from this pass the east border of the Contoocook valley is formed by Pack Monadnock, Temple, Kidder, and Barrett mountains, which extend in a continuous range through the west portions of Temple and New Ipswich. Northward this valley has a high eastern water-shed two to four miles from the river, with no deep depression till we reach the pass through which we have supposed a former outflow towards Piscataquog river. The culminating points of this water-shed are at its south and north ends, in Crotched mountain and Craney hill.

When the melting of the ice-sheet had advanced so far as to open an avenue from this valley through Greenfield, we may suppose that large streams descended from the glacier to this point, by which the kames on the east side of the railroad south of the village, those between Hogback and Pollard ponds and along the road northward between Greenfield and Bennington, and those at Bennington station and for a mile north-west on both sides of Contoocook river, were in succession deposited. The fine alluvium of these streams was at first spread out in the level plain east of Cragin pond, while ice still remained over the area now occupied by this pond. A small lake was afterward formed by the melting of the ice on the north-west side of the pass. This lake received the finer drift brought down by the glacial rivers, producing the alluvial plain west and north-west from Greenfield.

A channel appears next to have been formed farther to the north-west, skirting the hills upon the east side of the valley and walled on the west by ice. This became filled by the nearly level-topped and terrace-like gravel and sand seen on the east side of the Manchester & Keene Railroad south from Bennington station, which seem to belong to the same date with the kames at this station and about Whittemore pond. The kames were probably formed in ice-channels which were narrow and somewhat higher than the former, with so rapid a descent that only coarse gravel was deposited in them by the summer floods, the sand being carried onward to the quiet waters of the channel below, which was an arm of the lake. With the full melting of the ice, however, such of the kames as had been formed over the middle of the valley sank to its bottom, and are found at a lower level than the principal deposits of fine gravel and sand, which remain nearly at their original height upon the hillside.

The kames which we find south-west from Bennington, and a large portion of those north of Whittemore pond, are principally composed of sand and fine gravel. They were probably deposited at the mouth of the glacial streams where these entered the lake, nearly all the modified drift which was brought from the melting ice being thus accumulated in mounds, ridges, and terrace-like banks. The want of continuity in these deposits appears to be due to the irregular rate of melting and to the varying slopes assumed by the terminal front of the ice-sheet, the latter being determined by this rate and by the contour of the valley.

The lack of stratified drift in the valley west from the Greenfield plain seems to show that the ice over this area, while it still confined the little lake on the east, had been melted nearly to this level, sending its alluvium to form this plain; and that the remainder disappeared from the valley without sufficient currents to form alluvial deposits. All the material which it still held was dropped as unstratified till, unless we except rare instances of kames like the isolated banks of sand seen on the hillside east of the river near the north line of Peterborough.

The first deposit belonging to this period that we meet in going up the valley is the high level-topped sand north-west from North Peterborough. This and other terrace-like deposits extending to Peterborough appear to be of similar origin with those already noticed south of Bennington station. Kames of the common type, composed of coarse gravel and sand, occur one and two miles farther up the valley; and they are increased in amount as we approach the line between Peterborough and Jaffrey, appearing to have come principally from Sharon on the south-east. We may suppose that these, as in Bennington, were deposited at the same date with the sand which partly filled the opening channel below. This was a branch of the lake, and the sand fell in irregular and thin deposits with stratification conforming to the sloping sides of the valley. The occasional boulders which we find embedded in the alluvial deposits of this lake appear to have been dropped by floating masses of ice broken from the glacier which bordered its shores.

Going down the valley we find evidence that the glacial melting advanced beyond Hillsborough Bridge, while its outlet continued to be through Greenfield. The last blockade of the ice-sheet in its retreat to the north may have been at Long fall, in the west part of Henniker, where the high hills leave a narrower space than usual for the passage of the river. The large proportion of sand in the kames of the north part of Bennington is what we should expect, if their deposition was at the mouth of glacial rivers where they entered the lake. The most important testimony, however, is given by high deposits of sand and fine gravel, like that on Hedgehog hill in Deering. The widened lake now filled the whole valley; and these deltas, brought in by glacial rivers or tributary streams, mark its height and shore line, and enable us to gauge the floods which were supplied from the melting ice.

The earliest of these lake-shore deposits are the plain of Greenfield and that of Hancock village. Both of these have the same height with the outlet, over which there as yet flowed only a shallow stream. When the lake had advanced north to Clinton village in Antrim, the depth of its outflow was probably 20 feet, as shown by a level-topped ridge of sand and fine gravel exposed on the north side of Great brook and the road, a quarter of a mile east from Hastings's mill. This deposit extends a quarter of a mile to the north, and also occurs south of this stream, by which it was formed about at the level of the lake. High sand was also found three miles farther north, on the water-shed between Cochran brook and North Branch, at the south-west side of Riley mountain. This is two and a half miles due west from that on Hedgehog hill. Both these deposits are level-topped deltas of glacial streams that descended to the lake from the north, having the place of their inlet determined by the gap of the adjacent hills. Their heights are the same, and show that at the time of their formation 50 feet of water poured over the outlet in Greenfield. Somewhat later, when the lake reached its greatest extent and received its largest tribute from the more rapidly melting ice-sheet, the depth of water discharged was 80 feet, as shown by a delta-terrace half a mile south-west from Hillsborough Centre, and by plains which occur at the same height north-east of Hillsborough Upper Village. All these deposits are level-topped, or nearly so; and their position is generally on steep hillsides, with no barrier, if the drainage had been the same as now, to prevent their being carried forward to the bottom of the valley. Other deltas similar to these might probably be found by a more thorough exploration of the ancient lake shore.

*Heights of the Outlet and Deltas of the Lake which filled the Contoocook Valley through Hillsborough County in the Champlain Period.**

Outlet of lake, 1½ miles south-east from Greenfield, being the lowest point of water-shed between Contoocook and Souhegan rivers (2 feet lower than the railroad summit), 863.
Cragin pond, 830.
Greenfield station, 834.
Pollard pond, 810.
Delta cut by the railroad ½ mile north-west from Greenfield station, nearly the same in height with the fair-ground, 864.
Delta at Hancock village, 862.
Delta at Clinton village, Antrim, 883.
Delta south-west of Riley mt., Antrim, 912–915.
Delta on Hedgehog hill, Deering, 905–920.
Delta ½ mile south-west from Hillsborough Centre, 940.
Delta north-east of Hillsborough Upper Village, 942.
Kames at church and cemetery between Hillsborough Upper and Lower Villages, 930.

The depth of this lake was from 200 to 350 feet, as will be seen from the following:

Heights along Contoocook River.

Head of Long fall, near county line, 546.
At Hillsborough Bridge, foot of falls, 564; lower dam, 576; upper dam, 591.
At Bennington, foot of falls, 606; Paper-mill pond, 635; Kimball's dam, 645; King's dam, 655; Whitney's dam, 668; Powder-mill dam, 676.
Foot and head of fall at North Peterborough, 714–724.
Same at Peterborough, 727–734.
River at county line, about 875.

At length the melting of the ice along the lower part of the valley at the north-east met the already open portion which extended through Hillsborough county, and the drainage of the basin took its present course to the north. The erosion of the high deposits in the south part of Peterborough and the tribute of streams near the source of the river now supplied the low alluvium which extends for two miles below North Peterborough. The kames in Bennington probably also suffered considerable erosion, which, with the important streams on the west, furnished the similar low alluvial deposits of Antrim, Deering, and Hillsborough.

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* The heights from Greenfield to Paper Mill Village inclusive, given in Vol. I, p. 268, are too low, requiring the addition of 36 feet to agree with recent surveys of R. S. Howe for the Hillsborough & Peterborough Railroad, and with those of Hon. J. A. Weston for the Manchester & Keene and Monadnock railroads, published in Vol. I, p. 271. The heights given above are derived from the profiles of these railroads, or from special survey. They are stated in feet above the sea.

Our levelling to determine the height of deltas gave opportunity to note also the water-power of two tributaries of the Contoocook.

Heights along Great Brook, Antrim. Mouth of brook, 600; Thompson's mill-pond, 624; Goodell's saw-mill pond, 641; Goodell's next pond, 657; Poor's saw-mill pond, 672; Goodell's cutlery-shop pond, 703; Kelsey & Co.'s pond, 717; Baptist and Methodist churches, South Antrim, 719; road at foot of sand delta, Clinton village, 853; hay-scales platform at Clinton village, E. Z. Hastings's house, and his mill-pond, each, 914; Gregg's pond, according to an old survey, 1064.

Heights along North Branch in Hillsborough and Antrim. Mouth of Branch, 592; mouth of Beard's brook, near foundry, 600; Foundry mill-pond, 618; Young's (formerly Dickey's) mill-pond, 702; Tannery mill-pond, 728; still water, ¼ mile above Hillsborough Lower Village, 750. (The following heights of this stream in Antrim are from survey by G. C. Patten, in 1874.) Foot of rapids, ⅓ mile east of W. Curtis's, 755; Curtis's dam, 852; foot of falls at North Branch village, 862; Parkhurst's dam, 902; at Boutwell's bridge, 1 mile above this village, 985; proposed reservoir of 100 acres above do., 1025; J. Loveren's dam, 1077; foot of falls below do., 1024.

MODIFIED DRIFT OF WINNIPISEOGEE AND SQUAM LAKES.

The beauty of Winnipiseogee lake is due to its multitude of irregularly grouped islands, to the three long bays or arms into which its north end is divided, and to the winding outlines of its shores. The water-shed which bounds its basin reaches no point more than seven miles distant from the lake.* It passes over Belknap, Cropple Crown, and Ossipee mountains, and Red hill, which rise from 1,500 to 1,900 feet above the lake; but its other highest points are hills of half this height or less, which descend steeply to the west and south shores but have more gentle slopes on the east and north. Somewhat farther distant, at the north, the view from Winnipiseogee embraces Chocorua, Paugus, Passaconaway, Whiteface, and Sandwich Dome, which form the southern front of the White Mountains; and from many parts Mt. Washington is also visible. To know this scenery fully, the lake must also be seen from the mountains and hills by which it is environed. The most magnificent of these views is that from Red hill, which overlooks both Winnipiseogee and Squam lakes.

The depth of Winnipiseogee lake was measured by the Lake Company at the same time that the survey of its area was made. The deepest place found was a short distance off the east shore of Rattlesnake island, opposite to its southern and lowest peak. The depth at this spot was slightly more than 200 feet. Between Rattlesnake and Diamond islands it was 190 feet; in Alton bay, opposite Fort and Gerrish points, 100 feet, and at three fourths of a mile from its south end, 80 feet; in the broad portions of the lake, between Rattlesnake and Cow islands, from 100 to 150 feet; and between Cow island and Center Harbor, from 50 to

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* The topographic features of this district, and the areas of Winnipiseogee lake, its islands, and its hydrographic basin, are stated in Vol. I, pp. 203–205, 300, and 306–308.

75 feet. The pre-glacial outlets from this basin were along the present course of the Winnipiseogee river and south-east from Alton bay towards Cochecho river. Both of these old outlets are partly filled with till or modified drift; but it is certain that if these materials were wholly removed a large portion of the lake would remain, bordered by rock on all sides.

The lowest points in the water-shed around Winnipiseogee lake, with their heights in feet above the lake, are the following: Summit on railroad between Meredith Village and Pemigewasset valley at Ashland, 166, ten feet below the natural surface; at two and a half miles north from Meredith Village, about 140, and at same distance north from Center Harbor, about 100, these points being the lowest between this and Squam lake; the "Varney pass," between Moultonborough and the Bear Camp valley, about 150; summit on railroad between Wolfeborough and Salmon Falls valley, 164; between Smith's pond and Cook's pond, about 200; summit on railroad between Alton Bay and Cochecho valley, 72; and near Lily pond in Gilford, between the lake and Long bay, about 75 feet. The two last of these places show by their modified drift that they were formerly outlets of the lake.

These lake basins lie upon the south side of the White Mountains, from which source we might expect a greater depth of ice to move southward and cover this area near the close of the glacial period than would at that time remain in other parts of the state to the east and west. The ice-sheet probably lay over Squam and Winnipiseogee lakes in a broad mountain-like ridge till after it was almost wholly melted away over the lowlands of York county, Maine, in the basin of Ossipee lake, and for some distance along the Bear Camp valley. The ice-current was thus changed in direction on this side, and the last striæ marked on the ledges differ much from the prevailing course of about S. 40° E., being deflected towards the east or even to the north of east. This is shown by the following observations, all of which are reduced to the true meridian.*

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* The magnetic needle has a declination of 12° to the west. (See map, vol. i, p. 154.)

Courses of Striæ about Winnipiseogee and Squam Lakes.

On the North-East and East Side.

Nearly all of these are deflected easterly from the prevailing course of the ice-sheet; probably because of its earlier melting in the basin of Ossipee lake.

In Holderness.
Road over Squam mountain, S. 60° E.
In Sandwich.
At west line on road to Ashland, S. 80° E.
Near north-east corner of Squam lake, N. 85° E.
At north foot of Red hill, N. 80° E.
In Moultonborough.
Near south-east town line, S. 55° E.
In Tuftonborough.
Near Melvin Village, S. 25° E.
At Tuftonborough Corner, N. 70° E.
Two miles south of last, N. 80° E.
One half mile farther south, E.
(The two last in Tuftonborough are on the hills west of Lower Beech pond.)
In Wolfeborough.
West side of Trask hill, S. 85° E.
Summit of Trask hill, S. 50° E.
One mile north-east from Wolfeborough Centre, S. 40° E., and E.
Porcupine ledge, S. 60° E.
In Brookfield.
North corner of town, S. 55° E.
Two miles south of last, S. 70° E.
North side of Tumble-down Dick, S. 75° E.

On the West and South-West Side.

These show the general direction of the ice-current, coinciding nearly with the longer axis of Winnipiseogee lake.

Ashland village, S. 40° E.
Center Harbor, commonly S. 40° E.
In New Hampton.
Above clay-bed, two miles south-east from Ashland, S. 35° E.
Harper's hill, S. 50° E.
New Hampton centre, S. 40° E.
New Hampton village, S. 50° E.
In Meredith.
Hill north-west from Meredith Village, S. 40° E.
Meredith Centre, S. 25° E.
Highest hill, Meredith Neck, S. 40° E.
In Gilford.
North part, near lake, S. 35° E.
Hill north-east from Lake Village, S. 35° E.
North-east part, near lake, S. 40° E.
In Alton.
Ridge west of Alton Bay, S. 40° E.
Town line, east of Alton Bay, S 40° E.
In New Durham, commonly S. 40° E.

The departure of the ice-sheet along the Merrimack and Pemigewasset valley appears also to have proceeded somewhat more rapidly than upon the higher land on its east side, so that over Winnipiseogee and Squam lakes the drainage from the melting ice was outward both to the east and west.

The noticeable feature in the surface geology of these lakes is the absence of modified drift. Their shores are chiefly of coarse glacial drift or till, with occasional ledges. The neighboring basin of Ossipee lake, on the contrary, is characterized by very extensive and probably thick deposits of modified drift, presenting a remarkable contrast. These deposits are also abundant in the Pemigewasset valley on the west. Their conspicuous absence from these intervening basins needs to be accounted for, and this seems to be due to different rates of progress in the departure of the ice. The later continuance of the ice-sheet over these lakes turned all the drainage from the south side of the White Mountains into the Ossipee basin and Pemigewasset valley, and even caused the modified drift, which was contained in this part of the ice, to be mostly carried away. Our explanation of the remarkable deflection of striæ on the east border of these lakes is thus attested also by the modified drift, as by a separate and independent witness.

In describing the modified drift of this area, we will proceed from the mouth of Winnipiseogee river to the Wiers, and thence northward, including Squam lake, and passing around Winnipiseogee. The extent of these deposits is shown on the general geological map in the atlas. The interesting beds of clay and rarely of sand, overlaid by till, which occur at numerous places about these lakes, constitute a peculiar class of modified drift found nowhere else in the state. The localities of ordinary modified drift will be first described, and afterwards the instances of clay or sand overlaid by till. An explanation of the probable mode of formation of these different deposits will then be stated.

The mouth of Winnipiseogee river at Franklin is 269 feet above the sea. Its fall in the last two miles of its course is 146 feet, and its whole descent from the lake is 244 feet. (See p. 103.) The modified drift of the Merrimack valley is well shown on both sides at Franklin, its highest terrace being 150 to 175 feet above the river; but the Winnipiseogee, for the last mile and a half before entering this valley, is bordered only by till or ledge. The first area of modified drift that we find on this stream lies between Cross's mill-pond and Tilton, extending about a mile along the river and as far to the south, where it lies principally on the west side of the railroad. This deposit of sand and gravel has a height 30 to 50 feet above the river, slightly exceeding the upper terraces of the Merrimack at Franklin.

At Tilton, and for a mile above, the river has no modified drift. In the upper part of this distance the very steep slopes of till between which it flows indicate that a channel 50 feet deep may have been excavated in this material by the river. We next come to the largest area of modified drift found on this river. This extends nearly two miles along its north-west side, bordering Little bay nearly to East Tilton. A large part of this deposit was brought by the tributary which comes from Sanbornton Square. An interesting kame, forming a ridge of very coarse water-worn gravel, 30 to 40 feet high and a quarter of a mile long, lies on the west side of this stream at the margin of the modified drift. From its east side a plain of coarse gravel, 30 to 50 feet above the river, extends a third of a mile eastward, beyond which to Little bay the height is less, being 10 to 20 feet above the bay, and the material is finer gravel or sand. The edge of the high plain of coarse gravel is cut by the railroad; and the section shows the upper fifteen feet to consist of levelly stratified gravel, with its largest pebbles one foot or more in diameter, underlaid by several feet of sand, which is partly horizontal and partly oblique in stratification. The gravel is interstratified with the upper portion of the sand. This fine alluvium was probably brought by the large stream which comes in from Belmont, joining the Winnipiseogee from its opposite side at a short distance farther east. This tributary is bordered on the north by a wide sand plain, about 30 feet in height, which extends nearly two miles above its mouth. This was deposited in the Champlain period, since which time the stream has excavated a considerable portion of its plain, forming a wide meadow along its last mile. Previous to any erosion, this plain appears to have been continuous across the present channel of Winnipiseogee river; and we thus find a portion of it underlying the coarse gravel which came from the opposite direction, being supplied abundantly at a little later date as the melting of the ice-sheet advanced to the north-west.

The successive expansions of the Winnipiseogee river are called bays. In ascending the river they are met in the following order:

	Approximate area.	Height above sea.
Little bay, ...	.5 square miles.	473 feet.
Sanbornton bay, ...	1.0 "	490 "
Great bay (Winnisquam lake), ...	5.0 "	490 "

Round bay, ...	.5 square miles.	501 feet.
Long bay (of same height with Winnipiseogee lake),	1.9 "	513 "

The east and north shores of Little bay and the south and west shores of Sanbornton bay north to Mohawk point, with the river between them, are destitute of modified drift; but it is found on the east shore of Sanbornton bay, extending along the railroad from Ephraim's cove to Winnisquam station at the bridge between this and Great bay. This deposit consists principally of gravel, much of it containing pebbles a foot in diameter, and it has a height of 10 or 20 feet above the bay. Its origin, and the cause of its accumulation along this margin of the bay, appear to be shown by the kame of coarse gravel, from 10 to 15 feet in height, which forms Mohawk point, and is connected with the east shore by a low bar of gravel and sand. On the west side of the bay, opposite Mohawk point and only a short distance from it, a higher bank of the same gravel occurs. These kames appear to have been formed in the channel of a glacial river, which came down from the north-west at a time when the ice covered the greater part of this bay. It had been melted away only along the east shore, which therefore received from this and other streams a border of modified drift. The sand plain, about 20 feet in height, which extends along the west side of the bay for a mile north from these kames, was brought down from the same direction after the ice had retreated from this area.

The next deposit of modified drift that we find is the sand plain on which the south part of Laconia village is built. This is about one third of a mile square, and from 15 to 20 feet above Great bay. One half mile farther north a small deposit of gravel and sand is crossed by the railroad on the south-east side of Round bay. No modified drift was seen at Lake Village, and the hills rise steeply on each side. In digging for foundation for the dam and mills here, sand is said to have been found under sixteen feet of till. This sheltered situation has probably preserved a remnant of alluvium, which was deposited before the glacial period or during some temporary withdrawal of the ice. A half mile north-east from Lake Village we come to a sand plain, from 10 to 20 feet in height, which extends a half mile to the north and east. Before the ice-sheet was melted away at the Wiers, the waters from the lake had their outlet at this place, passing over the low water-shed on the east near Lily pond. On the north-west side of Long bay a small brook has brought down a deposit of sand and gravel which is crossed by the railroad.

The mouth of Lake Winnipiseogee is a narrow channel called the Wiers, because of dams made here by the Indians for taking fish. No modified drift of the ordinary kind occurs near this outlet or along the shore of the lake north-west to Meredith Village. A small kame-like deposit of coarse gravel and sand, 40 feet above the lake, occurs a short distance north-east from Meredith depot; and alluvial sand about 25 feet in height borders the brook which flows into the head of this bay and extends half a mile eastward along the lake shore. Wukawan lake and Long pond, which lie on the north-east side of the railroad above Meredith, are the same in height, being 36 feet above high water in Winnipiseogee lake. They are separated by a swampy area, but with this exception are surrounded on all sides by till or ledge. Another Long pond, one half mile east of Center Harbor and about 10 feet above the lake, has a small area of alluvial sand and clay at its outlet.

The shores of Squam and Little Squam lakes, like those of Winnipiseogee, are almost wholly composed of till or ledge. The only modified drift seen in a journey by the roads along the east and south sides of Squam lake was at a point a mile and a half south-east from White Oak pond. This consists of kame-like gravel and sand, irregularly stratified, with occasional large boulders on the surface. A well defined kame, 15 to 25 feet high, extends a fourth of a mile west from the bridge between these lakes along the north shore of Little Squam. This ridge contains frequent angular boulders up to three or four feet in diameter. Squam river above Ashland is bordered by low alluvium a few hundred feet wide. Its total descent is 110 feet, nearly all of which is utilized for water-power.

At the head of Moultonborough bay we find swampy land along its east shore for a mile, and farther east an extensive deposit of sand, undulating and partly covered with pines, reaching a mile from the lake, with its highest portions 40 feet above it. The next modified drift is four miles to the south-east at Melvin village. Melvin river here brought down in the Champlain period a small plain of gravel and sand, which since that time has been partly excavated by the stream, and partly undermined and carried away by the lake, so that it now forms a terrace 20 feet high. Another tributary to the lake a mile farther south-east is bordered by terraces of similar height near its mouth. On the north-east side of Twenty-mile bay, two miles south from Melvin village, a bold shore of coarse till, with many large boulders, is bordered by an old beach, about 300 feet long and 100 wide, which slopes from the water's edge to ten or twelve feet above high water. It is composed of fine stratified sand, which is clayey below a foot or two of the surface. No tributary occurs here, but a small stream at an eighth of a mile south-east has brought down considerable alluvial sand, none of which, however, lies more than five feet above high water.

Kames. Half a mile farther south we find a kame extending two thirds of a mile from north-west to south-east along the top of a hill about 100 feet above the lake. It does not form a definite ridge, and could hardly be distinguished from the till by its contour. Its materials are coarse and fine gravel and sand interstratified. Boulders are enclosed in many portions, but a well at Charles G. Edgerly's, 30 feet deep, encountered no boulders, being all the way through sand or fine gravel. Nineteen-mile bay and brook are a half mile farther south. Here the road passes over the alluvium brought down by this brook, which, like that at the head of Twenty-mile bay, is only three or four feet above the lake. Nineteen-mile brook is bordered by considerable widths of low alluvium for two miles above its mouth, to where it is crossed by the road a mile and a half south from Mackerel Corner. From the brook to this village, and for a half mile farther north, kame-like deposits of limited amount are seen here and there at heights of 100 to 200 feet above the lake. East from this road interesting kames extend more than a mile along the north-east side of Nineteen-mile brook. These cover a width of a fourth of a mile, consisting of successive small plains from half an acre to two or three acres in extent, usually surrounded by hollows, and rising one after another from 30 or 50 to 100 feet above the stream, or fully 150 feet above the lake. These small level-topped deposits consist of sand and water-worn gravel, with the largest pebbles about one foot in diameter. Boulders are occasionally but not frequently enclosed. These kames begin about two miles south-east from that described between Twenty-mile and Nineteen-mile bays. These and the similar deposits which occasionally appear about Mackerel Corner probably had a common date and cause. Advancing to the south-east we leave the modified drift, but cross a water-shed which is probably lower than the highest of these kames, and thence follow Hersey brook to Smith's pond. A sandy plain, about 50 feet above the pond or 75 feet above the lake, is found on the west side of this brook near its mouth, covering about half a mile square. The shores of this pond, like those of the lake, are almost entirely till or ledge.

Upper Beech pond, covering perhaps 150 acres and about 300 feet above Lake Winnipiseogee, is situated a mile and a half north-east from the kames last described. Its outlet is to Ossipee lake by Beech river, but only a very slight barrier at its south-west side prevents its flowing to Winnipiseogee lake by Nineteen-mile brook. This barrier consists of a kame, which in its north-west portion is a nearly level plain three or four acres in extent, but for several hundred feet south-east from this it is narrowed to a mere ridge. The gravel of the small plain is but slightly water-worn, the rock fragments being from a foot to a foot and a half in size. The ridge consists of sand or finer gravel, in which fragments larger than six inches are uncommon. This whole deposit is bounded by steep slopes both against the pond and on the opposite side. The height of the plain is 20 to 30 feet above the pond; that of the ridge declines to only ten feet, and at its east end to only three feet above the pond, while its south-west slope falls abruptly to 20 or 30 feet below it. Large springs fed from the pond issue at the bottom of this bank. Except at this point and its outlet, this pond is surrounded by high hills; and no other kame-like deposits occur on its shores or in the steeply sloping valley that descends towards the south-west from this barrier.

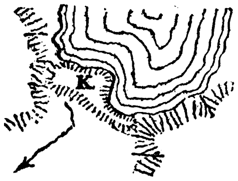

Fig. 27.—South end of Upper Beech Pond, Wolfeborough.
Scale, 1 inch=¼ mile.

The shores of the lake through Wolfeborough have no modified drift worthy of note. It is next met with in Alton, about a mile east from Fort point and the mouth of Alton bay. Proceeding eastward from the mouth of the bay, we soon come to a hill more than 200 feet high, and at its east side find an area of considerable width, which is only 50 to 60 feet above the lake, and extends about two miles from north to south between the lake and the bay at Gerrish point. Where this area is crossed by the road to Fort point, it is a level, sandy plain, but southward it is partly occupied by a similar plain and partly by kames, which form mounds and ridges, extending from north to south, with the intervening hollows 20 to 30 feet deep. The material of the kames is water-worn gravel, containing pebbles up to one or two feet, and often enclosing boulders of all sizes up to six or eight feet in diameter.

On the west shore of Alton bay, south-west from Gerrish point, we find kames and level-topped mounds of interstratified sand and gravel, with occasional large boulders enclosed or on the surface. These rise about 50 feet above the lake, and border its shore for nearly a half mile, extending southward from the mouth of the principal valley or opening among the hills on its west side. With these exceptions, till and ledge form the shores of this bay till we come to its end at the south extremity of the lake.

From Alton Bay station a continuous area of modified drift, varying from one fourth of a mile to nearly two miles in width, extends towards the south-east along Merrymeeting river and across the low water-shed only 72 feet above the lake, which separates this basin from the head of the Cochecho valley. A kame, forming a well defined ridge 40 to 60 feet high, extends nearly a mile southward from the lake. It lies for the first third of a mile on the west side of the railroad, by which it is then crossed twice, thence continuing to the south close upon the west side of the river. It is mainly composed of coarse water-worn gravel, which contains rounded boulders up to two or three feet in diameter. It also contains occasional angular boulders of larger size, and in some portions the ridge is made up almost wholly of such angular blocks one to four feet in diameter. Deposits of fine gravel and sand reach an equal height along this distance on the east side of the river.

Alton village is situated about 60 feet above the lake on a level plain, the north part of which is coarse gravel full of pebbles three inches to one foot in diameter, while its south portion is finer gravel or sand. To the south-east the alluvium is nearly two miles wide, and consists of plains of sand or fine gravel, and low, marshy meadows. The former do not exceed 60 to 70 feet above the lake, or about 30 to 40 above Merrymeeting river. No kames were seen between Alton and New Durham station; but a short distance from this station a kame 25 feet in height was seen on the west side of the railroad. The wide alluvial area here forms a water-shed; and half a mile farther south-east we come to a considerable stream, which is one of the principal sources of Cochecho river. The modified drift continues about a half mile farther, consisting of very coarse irregular kames on the west side of the stream, while on the east side is a plain of fine gravel or sand about 30 feet in height. The next four miles of this valley, extending nearly to Farmington, has a rapid descent, and is nearly destitute of modified drift.

North-west from West Alton frequent kame-like deposits are found along the road for three fourths of a mile. These consist mainly of sand and gravel interstratified, with numerous boulders enclosed or on the surface, and are disposed in nearly level-topped, irregular terraces, with gently-sloping escarpments. Similar kame-like terraces occur in Gilford at two and three miles farther to the north-west. These all lie upon hill-sides of till or ledge, which border the lake, at a height of about 75 feet above it. Alluvial sand only 5 to 10 feet above the lake has been deposited by a small brook near the north-east corner of Gilford, and also by a stream which enters the lake below the last mentioned terrace, coming from the valley east of the Belknap range.

Two miles farther west we come to a large alluvial area, which borders Gunstock river and Meadow brook, extending nearly a mile in width from the lake to Lily pond, thus forming the water-shed probably not more than 75 feet in height between the lake and Long bay. This modified drift is gravel, sand, or fine silt, with a quite regular surface which slopes gently to the lake. A considerable tract of it is interval, being overflowed by the freshets of Gunstock river. A continuous area of modified drift appears to extend north from Lily pond to the lake at a point about one mile east of the Wiers. We here find, south from the bridge to Davis island, very well marked kames, which form north and south ridges 50 feet above the lake. They consist of water-worn gravel, with pebbles up to one foot in diameter, and enclose occasional boulders. A terrace of similar materials borders the hills on their west sides.

All the ordinary modified drift which we found in our exploration of these lakes has now been mentioned. A more remarkable class of deposits, which has not been met with in other parts of the state, remains to be described.

Modified Drift overlaid by Till.

Numerous beds of clay, nearly horizontal in stratification, but overlaid and underlaid by coarse unstratified glacial drift or till, are found on hillsides up to heights 200 or 300 feet above Winnipiseogee lake. Similar beds of sand appear on hills east of Alton bay. In describing these deposits, we will begin at the Wiers, and proceed around the lake in the same order as before.

The first of these clay beds overlaid by till is beside the railroad, a short distance north-west from Wiers station, where it is worked by A. Doe & Son for brick-making. This is blue clay, finely laminated and nearly horizontal, dipping perhaps 5° to the south-east. At one place where the excavation has reached the bottom of the clay, it is underlaid by four feet or more of quicksand. This is at a height of about 25 feet above the lake. The thickness of the clay is fully thirty feet, and it is exposed by an excavation about 100 feet square. The clay is directly overlaid by two to six feet of coarse till, which contains angular boulders up to six feet in diameter. This is upon a hillside which rises 100 feet higher, and appears on the surface to be wholly composed of till; but much of this is probably underlaid by a stratum of clay at no great depth. This clay comes to the surface at A. Doe's house, about 150 feet above the lake, where a well 27 feet deep encountered no other material. The well filled with water from thin, sandy layers; but most of this clay did not show its lines of stratification plainly, and was inclined to break with a conchoidal fracture into small pieces. At both places the clay is free from stones or gravel, except that small boulders, usually less than a foot in diameter, are occasionally found embedded in it.

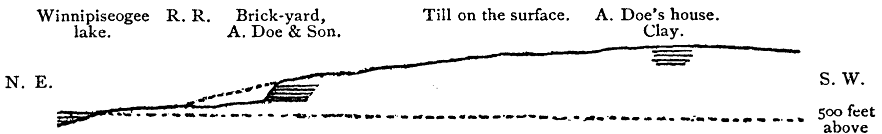

Fig. 28.—SECTION NEAR WIERS. Distance, ⅓ mile; vertical scale, 1 inch=400 feet.

In New Hampton, two miles south-east from Ashland, a large deposit of clay similar to that at the Wiers occurs on land of Oren Plaisted, lying on the east slope of a high hill. The drainage is into the Pemigewasset river. The height of this clay is, by estimate, 350 feet above the river and nearly 250 feet above its highest terraces, or about 800 feet above the sea. A well at Mr. Plaisted's house showed 15 feet of till underlaid by 18 feet of clay. A few rods farther north, at nearly the same height, the clay is covered by only one or two feet of till. About fifteen rods farther north-west, on the steep hillside and some 30 feet higher than the foregoing, a small excavation for brick-making shows a bed of clay ten feet thick, and probably extending deeper, overlaid by two feet of till. This clay is free from pebbles, but occasionally shows layers of sand half an inch thick. Its stratification is nearly level, but slightly anticlinal, dipping a few degrees at the north and south sides.

Some light is probably thrown upon the origin of these deposits by a section (Fig. 29) which was observed by the roadside between Ashland and Little Squam lake. On the surface was coarse upper till, 3 feet deep, showing no marks of stratification, and consisting of sand and gravel mixed with abundant angular boulders of all sizes up to four feet in diameter. Next was a dark blue clay, 10 feet thick, plainly stratified, but not finely laminated, and containing many fragments of rock up to six inches in diameter. Next below, and separated from the former at a definite line, was the compact unstratified lower till, which is here dark and clayey, and contains many glaciated stones up to a foot and a half in diameter.

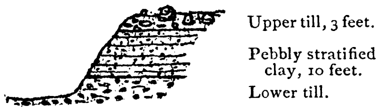

Fig. 29.—SECTION IN ASHLAND.

South of Squam bridge the steep north slope of a hill which rises from the shore of Little Squam lake has a layer of clay, stratified and free from pebbles, which is overlaid by one to three feet of till. The clay is four or five feet deep, but how much deeper is not known, and it is said to extend from near the lake shore to a height 150 feet above it.

On the east side of Squam lake the farm of John Wiggin, in Moultonborough, has frequent deposits of clay similar to that last described. At about fifteen rods south-west from the house and about 100 feet above the lake, this was used for brick-making fifty years ago. The side of Red hill, which rises near at hand on the east, is said to have in many places, to a height 300 feet above the lake, a stratum of clay underlying one to three feet of coarse till. On the north side of this lake the clay on land of the Messrs. George, in the south-west corner of Sandwich, which was extensively worked for brick-making fifty years ago, appears from description to belong in the same class with the foregoing.

No deposits of this kind were heard of about the north end of Winnipiseogee lake from the Wiers to Melvin Village. The well of Mr. Stockbridge, in the eastern part of this village, about 25 feet above the lake, showed 6 feet of till underlaid by 10 feet of clay, followed by 6 feet of water-worn gravel, which contained copious springs. Less than a mile to the south-east a well at J. Tate's showed 8 feet of coarse till and then 4 feet of clay, underlaid by coarse, water-worn gravel. Chas. H. Copp's well, 400 feet farther south-east, showed 4 feet of coarse till, underlaid by 23 feet of fine, stratified blue clay, beneath which water came in abundantly from a thin layer of gravel which rested on a ledge. The former is about 30 and the latter about 50 feet above the lake. One mile farther south a similar deposit of clay, about 30 feet above the lake, has been used for brick-making. It lies a short distance east from the school-house near the head of Twenty-mile bay. On the south-west side of Black island, a mile distant from Melvin village, two or three acres, 10 to 15 feet above the lake, have a thin layer of till, with many large boulders on the surface, underlaid by clay, stratified and free from pebbles, at least four or five feet in depth.

At Wolfeborough, the hillside of till south-east from the bridge has an underlying stratum of clay. Wells at the Glendon house, about 25 feet above the lake, show some 6 feet of till, then an equal depth of clay with till beneath. Near the Pavilion, about 50 feet above the lake, a well showed 8 feet of coarse till, then 2 feet of ferruginous earth, then 12 feet of clay free from stones, underlaid by the compact stony lower till. About thirty rods south-east from the last a well passed through 8 feet of till, and then through 4 feet of clay, which was underlaid by till. About the same distance farther south-east a well at J. Hanson's found this layer of clay only one foot thick, occurring 10 feet below the surface. The last

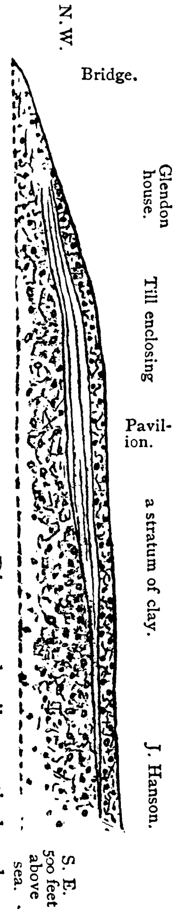

Fig. 30.—SECTION IN WOLFEBOROUGH VILLAGE. Distance, ½ mile; vertical scale, 1 inch=100 feet. The base of the section represents the level of the lake.

two places are only a few feet higher than that near the Pavilion. Nearly all that part of the village which lies south-east from the bridge is built on a thick mass of till, which encloses a continuous stratum of clay. North-east from the Pavilion a slope descends in about twenty-five rods to a small pond, which is tributary to the lake and of the same height. This slope has a surface of till, with numerous boulders; but excavations for brick-making show that the clay beneath has a thickness of fully 20 feet, with its bottom resting on till only a few feet above the lake. The till on the surface is 1 to 8 feet deep. This clay is free from pebbles, and is finely laminated in its lower portion, while its upper part sometimes crumbles into small angular pieces. No deposits of clay appear to occur in the thinner till which covers the hillside north-west from the bridge.

At Clay point in Alton, three miles south-west from Wolfeborough, the lake shore rises steeply from 10 to 40 feet, and from the top of this escarpment the surface, which is coarse till, has a very gentle upward slope. The lower part of this bank consists of a stratum of clay which was worked forty years ago for brick-making. This was at the end of the point where there was at least fifteen feet, and perhaps considerably more, of finely laminated blue clay free from pebbles, with its bottom nearly at the level of the lake. It was underlaid by a stratum of coarse, water-worn gravel, containing iron-rust. This abrupt bank, which extends around the point fully a quarter of a mile, has resulted from the excavation of the clay by the waves of the lake.

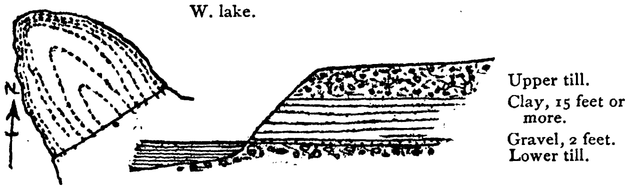

Fig. 31. Fig. 32.

Map and Section of Clay Point, Alton. Scale of map, 1 inch=¼ mile. Contour lines are shown for each 10 feet above the lake.

Near East Alton, two miles south-east from this point, a bed of gravelly and somewhat stony clay, at least seven feet in thickness, is overlaid by two or three feet of till at a height of about 200 feet above the lake. A mile and a half west from this place, clay of good quality, finely laminated and free from pebbles, occurs on the north and north-west side of a hill, at a height of 150 feet above the lake. Both these deposits have been used for brick-making, and the latter has been excavated at two places an eighth of a mile apart. It is overlaid by about two feet of till, and a well showed the thickness of clay to be 13 feet, under which was a water-bearing layer of gravel.

From this clay-bed a valley about 40 feet in depth descends to the south at the west base of the hill, which on this side is ledge. The bottom and the steep west side of the valley are composed only of modified drift, being fine silt or sand; while only till with many large angular boulders up to 10 feet in size forms the top of its west bank and the irregular surface, which thence descends westerly to the alluvial area previously described on page 129. The contour of this locality is shown in Fig. 33; and Fig. 34 shows the apparent position of the sand underlying the very coarse till. Less than a mile farther south a similar valley is seen from the highway on its east side a short distance north of M. Adams's house. The contour and probable section at this place are shown in Figs. 35 and 36. Here it

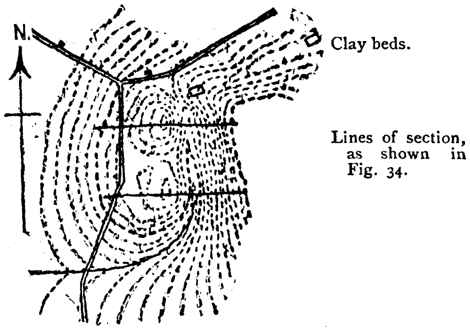

Fig. 33.—MAP OF A SMALL AREA IN ALTON, TWO MILES SOUTH FROM CLAY POINT.
Scale, 1 inch=¼ mile. Contour lines are shown for each 10 feet, the highest being 200 feet above the lake.

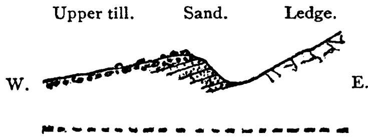

Fig. 34.—SECTION CROSSING FIG. 33.
Horizontal scale, 1 inch=⅛ mile; vertical scale, 1 inch=400 feet. The dotted line at the base represents the level of the lake.

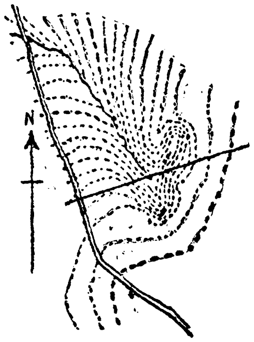

Fig. 35.—MAP OF A SMALL AREA IN ALTON, THREE MILES SOUTH FROM CLAY POINT.
Scale, 1 inch=¼ mile. Contour lines are shown for each 10 feet, the lowest being 50 and the highest 200 feet above the lake.

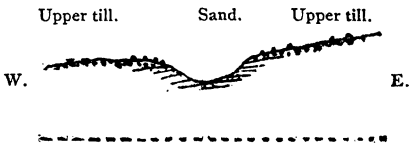

FIG. 36.—SECTION CROSSING FIG. 35.
Horizontal scale, 1 inch=⅛ mile; vertical scale, 1 inch=400 feet. The dotted line at the base represents the level of the lake.

appears that a thick deposit of sand underlies a thin surface of till upon a hillside between the heights of 100 and 200 feet above the lake. These localities have become noticeable because a great depth of sand has been excavated by rivulets. Probably thinner deposits of sand exist in many places underlying till, but not having an economical value like the clay, they have escaped notice.

At the north-west ends of Rattlesnake and Davis islands deposits of clay are found similar to that of Clay point, and in former times it has been excavated at both these places for brick-making. The same abrupt bank from 20 to 30 feet high forms the shore, and the surface of coarse till slopes gently upward from its top. The underlying clay-beds are free from pebbles and plainly stratified.

Review and Conclusions.

These numerous examples make it probable that many other similar deposits exist about these lakes, since their presence is not usually indicated on the surface. In considering the question of their origin, we notice that these beds of stratified clay and sand are uniformly overlaid by a comparatively thin covering of unstratified glacial drift, which in every instance is probably wholly made up of the loose, sandy, and very coarse material which we have called upper till. It is remarkable that no similar deposits are found on the hillsides without this thin covering of till. The examples found, however, do not lie in the pathway of any stream which could be supposed to bring the modified drift, or to excavate and carry it away if any had been left on the surface; instead of this they occur on the rounded slopes of hills at all heights from the lake shore to 200 or 300 feet above it. If any clay beds had been left in such situations without a covering of till, they would remain to the present time, and would be worked in preference to others for brick-making. It is also remarkable that these deposits frequently extend in a stratum of varying thickness over a considerable area of hillside, sometimes appearing to be continuous upon a slope which rises 100 feet or more in vertical height. In all cases, however, where the stratification has been seen, it is approximately horizontal and not conformable to the slope.

The section observed near Squam river in Ashland (p. 132) indicates the probable position and mode of formation of these deposits of clay and sand. They appear to lie between the two members of the coarse glacial drift, which we have denominated upper and lower till. In other portions of the state these are distinct from each other, and in a few instances they have been found to be separated by a thin layer of gravel or sand; but generally they are divided at a definite line, with no intervening stratum of modified drift. This section in Ashland shows that between the lower and upper till a depth of ten feet of stony stratified clay was deposited; and this seems to have taken place beneath the edge of the ice-sheet shortly before the completion of its melting, which contributed the three feet of upper till lying on the surface.

The ice-sheet probably remained in a high mountain-like mass over these lakes after it had disappeared on each side from the basin of Ossipee lake and from the lower part of the Pemigewasset valley. As the melting continued, the drainage over this area was frequently obstructed because the ice-sheet retreated from the lines of water-shed towards the middle of these hydrographic basins. The water seems then to have melted large open spaces beneath the ice near its margin, in which beds of clay and sand were deposited. This would occur at the various heights and in the situations where these beds are found, and the till which overlies them is shown by its material to be that which was contained in the ice-sheet and fell upon the surface when its melting was completed. We thus see how these deposits came to be spread over the slopes of the hills, thinly covered by large boulders and till. The frequent accumulation of such deposits in other parts of the state was prevented by unobstructed drainage from the melting ice. This modified drift overlaid by till does not therefore appear to bear testimony to a warm inter-glacial period, or even to any retreat and subsequent advance of the ice.

The course of the rivers which flowed from the melting ice-sheet over this area can still be pointed out. The extensive deposits of modified drift in New Durham and Alton mark a long continued outflow to the Cochecho valley. When the terminal front of the ice had retreated to a point a short distance north-west from Alton village, it seems to have remained nearly stationary during the deposition of the plain on which this village is built. At the same time the kame which lies between this point and Alton Bay was formed in an ice-walled channel. During the recent or terrace period portions of these deposits have been excavated by Merrymeeting river. The kames on the west side of Alton bay, a mile and a half farther north, were formed at a later date, while the outlet was in this direction. When the ice-sheet had retreated nearly to the mouth of this bay, the outlet from its melting over the lake at the north was along the low area a mile east of Fort point. As the melting of the ice advanced towards the north-west, the kame-like terraces near West Alton, and those in the north-east part of Gilford, were probably deposited at the mouths of glacial rivers. Their height is that which the lake held when its outlet was to the Cochecho valley. The series of kames in Tuftonborough and Wolfeborough (p. 127) was probably formed at nearly the same time by a glacial river from the north-west, after the ice had disappeared from the south end of the lake and from the basin of Smith's pond. The kames between Davis island and Lily pond indicate that the drainage from the ice-sheet was by this avenue before it was melted at the present outlet a mile farther west. A kame on the north side of Little Squam lake marks the outflow from the melting ice-sheet over that basin.

The other deposits of modified drift about these lakes have been brought down by short streams, and are scanty in amount because the principal drainage of this area in the Champlain period was outward on all sides. They appear to have been formed in the same way that deltas are spread out nearly level at the mouths of tributary streams, often at an elevation much above the floods in the main valley. The height of the lakes during this deposition may therefore have been the same as now. If they had ever stood for any long period at a greater height, the hill-sides of till would be marked by a line like that of the present shore. This is mostly composed of till, which presents a wall of boulders four or five feet high, its finer portion having been washed away by the waves.

MODIFIED DRIFT ALONG MAGALLOWAY AND ANDROSCOGGIN RIVERS.

Mr. J. H. Huntington has kindly supplied information in regard to the modified drift of the Magalloway and the upper portion of Androscoggin river. He has also mapped the alluvial areas along the Upper Ammonoosuc river. The general geological map in the atlas shows the extent of these deposits in New Hampshire, so far as definite boundaries can be drawn.*

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* The Androscoggin river system is noticed in Vol. I, on pp. 224–226, 301, 309–311, and 322.

The level tracts on Magalloway river are described as especially remarkable for the occurrence of sloughs or small ponds, which are almost invariably found at a short distance on one or the other side of the stream. The river-banks are everywhere low, and the wooded plains, extending in places one half mile from the river, with a height rising from 10 to 25 feet above it, consist of gravel, which is not often so coarse as to have pebbles a foot in diameter. These are the characteristic features of this river for most of its length, both above and below Parmachena lake. The only exceptions are the three or four miles just below this lake, and about two and a half miles, called Escahos falls, next above Wilson's Mills, where only the glacial drift is present, over which the river descends in rapids obstructed by boulders. Along the greater portion of its course the descent is very slight, and the crooked stream winds slowly from side to side along its gravel plain. There seem to be no kames on either this or the upper part of Androscoggin river.

The fine alluvium brought down by the Magalloway has filled up a considerable area about the mouth of Umbagog lake, forming an extensive bog at the border of the lake, and reaching a height of 10 to 15 feet along the lower part of this river's course and on the Androscoggin to Errol dam. There are no rapids below Wilson's Mills, and the Magalloway is navigated as far as to Wentworth's Location by a steamboat from the lake. On other sides this lake has mainly hilly and rocky shores. Its height is 1256 feet above the sea.

Clear stream, along nearly its whole course from Dixville notch to Androscoggin river, is bordered by low sandy plains.

The modified drift of the Androscoggin above Dummer, along the distance which has no road, is described as consisting of tracts of swamp, or of stratified gravel and silt in some places one half mile in width, having a height of 10 to 25 feet. These are along level portions of the river, which alternate with rapids where the glacial drift, or till, extends in gentle slopes to the stream.

The exploration of the Androscoggin river, with special reference to its modified drift, extended nearly to the east line of Dummer. Below this point the river flows south-westerly four miles to Pontoocook falls, and in this distance is bordered on the north-west side by considerable areas of alluvium from 20 to 30 feet above the river, extending from one half to three fourths of a mile wide on Newell's brook, and on the stream which is the outlet of Dummer ponds. These tracts consist mainly of sand or fine silt, and are very level and in many portions swampy. On the southeast side the river is bordered by a narrow margin of modified drift, beyond which the hills rise from 100 to 200 feet above the stream.

Pontoocook falls extend about a mile from the most western point reached by the river, which here flows between hills of till or ledge. Near the foot of these falls is Pontoocook bay, which is an expansion of the river containing several islands. This is bordered by sandy terraces; and thence southward for ten miles, extending through Milan and nearly to Berlin falls, the modified drift is continuous, being usually one eighth to one third of a mile wide upon both sides of the river. This consists of sand or gravel, which is not often very coarse. About half of its whole width is interval, being from 5 to 15 feet above the ordinary height of the river; and all above this is irregular in contour, with no well defined terraces, the modified drift reaching in irregular slopes about 40 feet above the river. The Androscoggin along this distance is nearly level, having a height of about 1,050 feet above the sea; and the hills on each side are of moderate height and gentle slopes.

At Berlin Falls the precipitous front of Mt. Forest rises close at hand on the west, and the river here enters the White Mountain area. Along the rest of its course in New Hampshire, and for some distance in Maine, the valley is closely bordered by high and abrupt mountains. From the head of Berlin falls the river descends nearly 200 feet in the first mile, and its current is rapid to the east boundary of the state, which it crosses at a height of 690 feet above the sea. For the first five miles of this distance the course continues to the south towards the highest of the White Mountains; but at Gorham the river turns at a right angle, and after flowing nine miles to the east it enters Maine. The very rapid portion of the river at Berlin Falls is destitute of any modified drift, and the channel is principally ledge. Below these falls the modified drift through Gorham and Shelburne is continuous on one or both sides, though often narrow, and it is nowhere more than a mile between the steep mountain walls which enclose the valley.

Through Gorham, the terraces which border the Androscoggin are 10 to 50 feet in height, and they are best shown on the west and south sides of the river. They consist almost wholly of gravel, which is often very coarse, and in the highest terrace is sometimes but slightly water-worn, and scarcely distinguishable from till. At the sharp bend of the river, a mile north-west from Gorham village, three terraces occur on the east side, 10, 20, and 40 feet in height. The latter appears to represent the ancient continuous flood-plain at the close of the Champlain period. The village of Gorham is built on a lower terrace, 25 feet in height, which extends nearly level for a mile between Moose and Peabody rivers. Remains of the ancient flood-plain form terraces of coarse gravel, from 20 to 30 feet higher, which occur on the north side of the Androscoggin opposite the mouth of Moose river, on the south side of the railroad in the west part of the village, and on Academy hill, which is an isolated remnant that escaped erosion because partly protected by ledges.

Peabody river, for a mile before entering this valley, is bordered by steep banks of extremely coarse modified drift, or perhaps till, from 40 to 100 feet high. The space between these banks was formerly filled with similar material, which has been excavated by the stream during the recent or terrace period.

In Shelburne the modified drift occurs principally at two heights. The upper terraces are the remnants of the river's flood-plain in the Champlain period. They are from 50 to 60 feet above the river, with a nearly level surface, and bordered by steep escarpments. Their material is usually gravel, which is frequently very coarse, but in some places it is mainly sand. A mile and a half east from Shelburne village, several small ponds occur in hollows upon this terrace plain. The lower terrace is interval, being only from 5 to 15 feet above the ordinary height of the river.

It is a noticeable feature of the intervals of this part of the Androscoggin and of the upper portion of Saco river, that they are often composed of a substratum of coarse gravel, containing pebbles one foot or more in diameter, above which is a layer of fine silt three to six feet thick forming the surface. The coarse gravel is like that which often forms the river's bed in the vicinity of the mountains; and these sections, which are exposed in the banks now being undermined by the river, show that it formerly had its channel in nearly the same place as now but at a greater height, having flowed upon the surface of the layer of gravel.

Since that time the river has been changing its course, and the overlying fine silt has been deposited from its floods upon the deserted river-bed.

MODIFIED DRIFT ALONG SACO RIVER AND IN THE BASIN OF OSSIPEE LAKE.

The areas which are occupied by modified drift in this part of the state are delineated on the general geological map in the atlas; and a special map on Plate VI shows the extensive plains about Ossipee lake.*

The south-eastern part of the White Mountain district is drained by the Saco, which has its farthest sources in Saco pond and Mt. Washington river. The water-shed at the Crawford house, which divides this from the Lower Ammonoosuc river, is formed by a deposit of very coarse modified drift (p. 62), which was swept down into this mountain pass in the Champlain period. Its height is 1,900 feet above the sea; and Saco pond, which fills a depression in this deposit, is 20 feet lower. The small stream which issues from this pond passes through the White Mountain Notch, falling 600 feet in the first three miles, and nearly as much more in the next nine miles. Along this distance it flows between lofty mountains, whose sides are often precipitous walls of rock. A fine view of this part of its valley is afforded from the top of Mt. Willard. Far above rise the rugged heights of Webster and Willey, almost vertical in their upper part, but below bending in graceful, regular curves, composed of materials which have fallen from each side and form an apparently smoothed hollow for the highway and river. The principal superficial deposits along this steep portion of the river are such rocky débris which has crumbled from the mountains, or the equally coarse unstratified till. In the bed of the stream these materials have become water-worn, but only limited deposits of gravel and sand are found. It is worthy of note, that in constructing the Portland & Ogdensburg Railroad the excavations yielded an abundance of sandy gravel suitable for ballast. To make a gradual ascent, this road is built along the side of the valley; and some of these excavations were two or three hundred feet above the stream.

At the west line of Bartlett the Saco is 745 feet above the sea. In the next eight miles to the mouth of Ellis river, it descends about 30 feet to the mile, flowing over modified drift. This consists of gravel and sand, and above the Rocky Branch these occupy an area one fourth to one half a mile wide, which lies mostly on the south side of the river, forming a nearly continuous interval 10 to 15 feet in height, which slopes with the stream, and irregular terraces which reach 25 feet higher.

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* This river system is described in Vol. I, on pp. 301, 311, and 312.

From the Glen station in Bartlett to Conway Corner the alluvial area averages fully a mile in width, lying in nearly equal amount on each side of the river. The greater portion of this is interval, from 10 to 20 feet in height, which is often seen to be composed of coarse gravel overlaid by fine silt, as on Androscoggin river. The flood-plain of the Champlain period is shown in the higher terraces of sand or fine gravel, 40 to 60 feet above the river, which are nearly continuous on both sides. North Conway is built on a wide portion of the east terrace. The form of these terraces, with their surface level but usually narrow and bounded by steep escarpments, and their correspondence in height on opposite sides of the valley, make it easy to understand that a wide plain once reached across the intervening area.

Along Seavey's falls, which extend about a mile east from Conway Corner, the Saco is bordered on both sides by slopes of till and ledge. The modified drift of the highest terrace, however, is continuous between Pine and Rattlesnake hills, and thence extends two miles to the east on the north side of the river; and on the south it reaches from Conway Centre to the north-east side of Walker's pond, and thence is nearly continuous, though narrow, eastward to Maine line. East from the outlet of Walker's pond, the interval between this terrace and the river on the south is not wide, but on the north it extends one half to one mile from the river, rising with a gentle slope to a height about 25 feet above it. On this side, the most elevated part of the alluvial area, as at Conway Street, is only a few feet above the reach of high water. The ancient flood-plain, which was from 40 to 50 feet above the present river, as shown by its terrace on the south, may have extended over this whole area. It would then appear that the river here began its excavation on the north side, and has been gradually cutting its channel deeper and deeper as it has slowly moved across this area southward. Remnants of the former high flood-plain are thus found at a nearly constant height above the river for fourteen miles, sloping in this distance more than 100 feet. The height of Saco river at the state line is about 400 feet above the sea.

Kames between Saco River and Six-Mile Pond.

Along the Portsmouth, Great Falls & Conway Railroad a very remarkable series of kames extends six miles, from near Conway to Madison station. The railroad survey shows that the water-shed here is very low. It is 516 feet above the sea, being only 70 feet above the Saco river at Conway, and only 60 feet above Six-mile pond (also called Silver lake). This low avenue is one half mile to one mile wide, extending nearly from north to south; it is bordered on both sides by hills from 300 to 500 feet higher, those on the west side rising in almost perpendicular cliffs. The kame begins at Pequawket pond, a mile south-west from Conway Corner and Saco river. A ridge 40 feet high forms the west shore of this pond, and is thence nearly continuous for about three miles southward, lying on the east side of the railroad and Pequawket brook, which drains the part of this low valley that is tributary to the Saco. This kame is nearly straight, and for the most part consists of a steep narrow ridge 40 to 75 feet high, being composed of interstratified sand and coarse gravel, with occasional large boulders. A quarter of a mile south-west from Pequawket pond the top of this kame becomes 200 to 300 feet wide, and is level like a terrace. An excavation shows that the stratification here is nearly horizontal in the interior of the deposit, which is sand or fine gravel, but it is abruptly inclined on its west side, conformably with the slope of the kame. Low, swampy areas and occasional small ponds lie on the west side of this kame, and are interspersed farther to the south among irregular ridges and mounds. These unfilled depressions prove that very little erosion has been effected by the present streams; and that these deposits of modified drift owe their form to deposition in the channel of glacial rivers, while the ice remained unmelted on each side.

The southern part of this series of kames lies principally on the west side of the railroad, covering an area a third of a mile wide, and bounded on the west by the precipitous face of Pine and Hedgehog hills. Along the lowest part of the valley, near the railroad, the ridges consist mainly of gravel with little clear sand, and are much coarser than in the north part of the series; but their pebbles are plainly rounded, and of such size as could be transported by strong currents of water. These kames are from 25 to 50 feet high, and extend in crooked north and south ridges which are frequently traceable a quarter or a half mile. Large angular boulders are occasionally found embedded in these water-worn deposits. In going westward we find these boulders more numerous; and the ridges, which become shorter and more irregular, are composed partly or wholly of angular materials. Near the foot of the hills these ridges reach about 100 feet above the railroad, and present the very irregular contour of typical kames, having steep sides and narrow tops, and enclosing bowl-shaped hollows; but they consist entirely of angular débris with no water-worn deposits, and in many places their surface is composed only of boulders with no earth to fill the interspaces. Between these moraines and the true kames seen along the railroad there is a gradual transition, the intervening ridges being partly morainic and partly kame-like in material.

A considerable area of low alluvium, without ridges, lies east of Madison station, separating this long series of kames from others of coarse water-worn gravel, which occur on the north-east shore of Six-mile pond. Near the head of this pond a similar ridge forms a small crescent-shaped island, concave towards the north.

Plains in the Basin of Ossipee Lake.

On the north-west side of Six-mile pond no distinct kames were seen, but deposits of very coarse water-worn gravel, with the largest pebbles one or even two feet in diameter, rise from 25 to 50 feet in irregular slopes. The level plains begin about three fourths of a mile south from Madison station, and the material in the next three miles gradually changes to very fine gravel or sand, so that the railroad cuts at the south end of this distance rarely show pebbles an inch in diameter. These plains occupy a large area in the south-west corner of Madison and the east part of Tamworth, and extend south along Six-mile brook, which separates Freedom and Ossipee, to the north-west side of Ossipee lake. (Plate VI.) Their soil is barren, its natural woody growth being scrub oaks and pitch pines. Their height at the north is about 40 feet above Six-mile pond, which is 456 feet above the sea; thence they have a slight southward slope of 15 or 20 feet in a mile, descending nearly to the level of Ossipee lake, which is 408 feet above the sea. In their western portion they are from 40 to 50 feet above Bear Camp river, which along its last six miles flows through fertile intervals. These cover areas from which the river has excavated the higher plain. The upper part of this river is also frequently bordered by intervals and terraces.

The shores of Ossipee lake are mostly low; and it appears that this area remains unfilled because sufficient material has not been supplied by inflowing streams. We cannot thus explain the unfilled hollows of Six-mile pond, and of Elliot and White ponds in Tamworth; for the level plain adjoining them is from 25 to 40 feet in height, and descends steeply to their shores. Probably masses of ice filled these depressions while the bordering plains were being deposited.

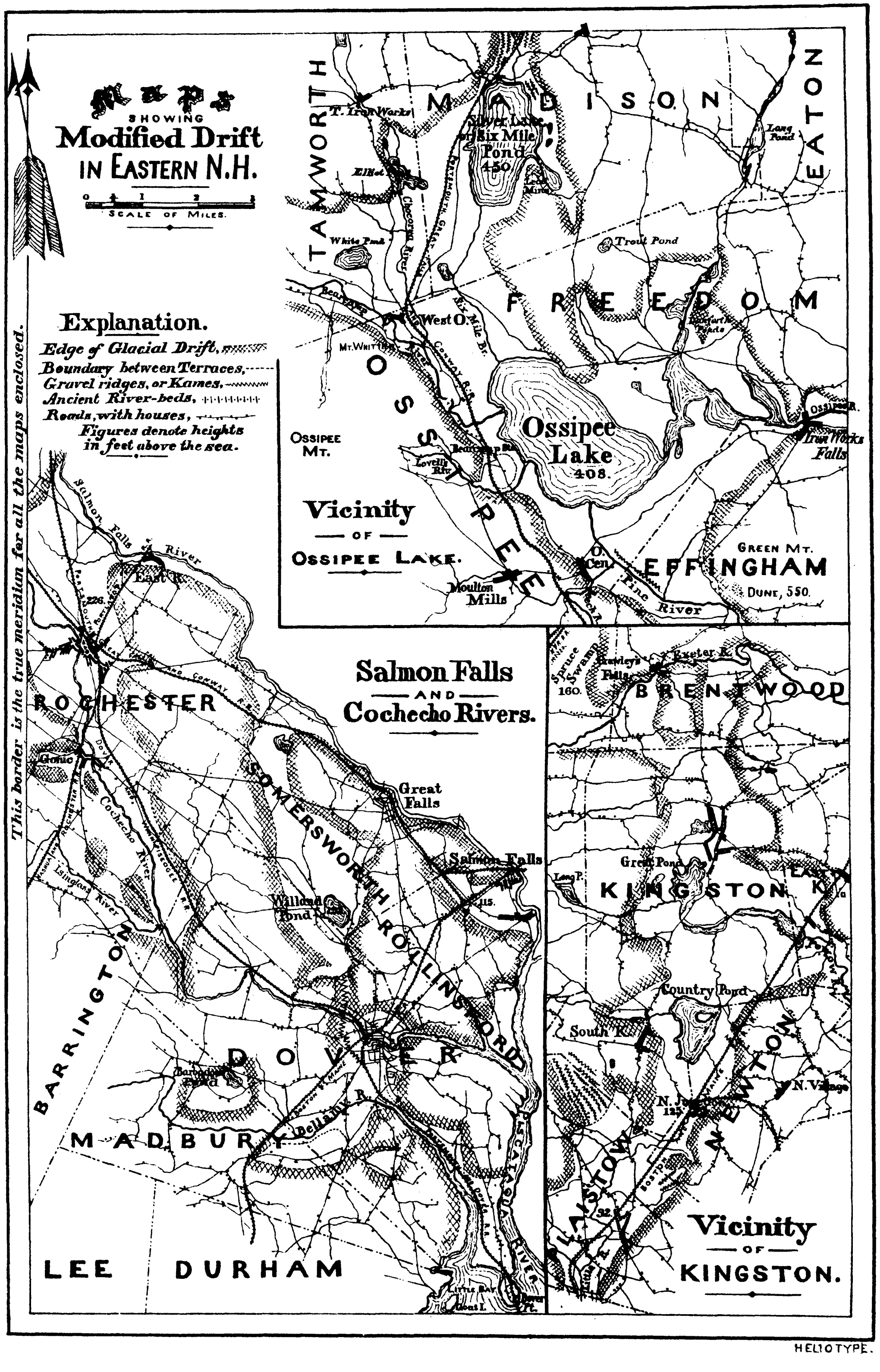
Till extends in a gentle slope to the margin of Ossipee lake along a distance of about a half mile on its north-east side. Barren pine-plains reach thence for three miles to the east. These are divided by the irregular chain of Danforth ponds, which have the same height with the lake. At Danforth bridge these plains are nearly level, and have a height of 35 feet above the ponds, to which they descend in steep escarpments. Their material is mainly sand or fine gravel; but coarse gravel, containing pebbles from six inches to one foot in diameter, is occasionally found, and appears to belong to kames which have been nearly buried beneath the fine alluvium.

Ossipee river, the outlet of this lake, flows over till at Effingham falls, and along its last mile before entering Maine. In the intervening three miles it is bordered by low modified drift, which extends to Swasey pond in Freedom, and forms an extensive tamarack swamp in the north-east corner of Effingham.

On the west and south sides of Ossipee lake the modified drift is one half mile to a mile and a half wide. Its highest portion is a delta-plain on the north side of Lovell's river, 40 feet above the lake. Elsewhere it is low, being swampy in many places, and rises only 15 to 25 feet above the lake, towards which it slopes.

These nearly level areas are bounded by hills and mountains, which rise steeply from the edge of the plains. The supply of modified drift was very abundant here, and fills three fourths of the natural lake-basin which is thus enclosed.

Plate VI.



HELIOTYPE.

A conspicuous dune, blown 125 feet above the low plains, occurs two miles south-east from Ossipee lake on the west foot-slope of Green mountain. A track of sand-drifts, now grassed over, reaches up to this from the north-west; and an old pine stump, standing where it originally grew, shows that since the clearing of the country a portion of the dune seven feet in depth has been swept from beneath it by the winds, being carried to the south-east and somewhat higher up the hillside.

Kames along Pine River.

South-east from Ossipee lake a continuous belt of modified drift extends along the entire course of Pine river, forms the water-shed between Pine River pond and Balch pond, and thence continues eastward along Little Ossipee river in Maine. These ponds are about 20 and 40 feet respectively below the lowest point of the water-shed, which is about 550 feet above the sea, or 140 above Ossipee lake, 12 miles distant. The width of the modified drift here is fully a mile, and it is not much narrower at any point. It occupies a comparatively straight valley, which is commonly bordered by high hills at each side. An exception to this is found in the south part of Effingham, where level sandy plains about 500 feet above the sea extend nearly continuous from Pine river to Province pond. Other level plains occur, as south-east of Duncan lake, between North Wakefield and the mouth of Pine River pond, and east of East Wakefield depot; but the greater part of this modified drift has an uneven surface, presenting small hollows, ridges, and mounds; and prominent kames, in ridges from 75 to 125 feet above the river, extend along the middle of the valley.

This series of kames or gravel ridges borders Pine river south-east from Ossipee Centre, but it is not well shown at the bridge in Effingham. Two miles farther south, where there were formerly a bridge and mills, it consists of a single narrow ridge, 100 feet above the river which flows at its foot on the east, and 30 feet above the plains which extend a mile south-west to Duncan lake. One mile southward this principal kame of the series is said to lie between White and Black ponds. Opposite Ossipee Corner the river crosses the line of this ridge, a half mile of which has been swept away. It next appears east from the mouth of Poland brook, and extends in a single ridge a mile to the south, with a height 50 to 75 feet above the low modified drift on each side, or about 100 feet above the river. It is then cut through by the river, but only a short gap is made; and it continues thence unbroken for more than a mile to the south-east, forming a nearly straight ridge 75 to 125 feet high on the west side of the river. On its east side the modified drift is narrow; and the road passes over a hill which affords a fine view of this kame, and others of less height which extend parallel with it, and fill nearly the whole valley for two miles below Pine River pond. At the mouth of this pond the principal kame seen was just north-east of the bridge, with a height 40 feet above the river. Kames of the same or less height occur along the shores of this pond, and form its islands. The water-shed between Pine River and Balch ponds is an area of kames, its lowest point being a hollow between high parallel ridges; and the same series continues south-east along the sides of Balch pond.

The material of these ridges is almost wholly water-worn, wherever it has been observed. It consists principally of gravel, which contains pebbles or rounded boulders up to two or three feet in diameter. Layers of sand are sometimes interstratified with this gravel; and angular boulders up to five or six feet in diameter are occasionally found. The more level areas of modified drift in this valley are also mostly gravel, with the largest pebbles frequently six inches to one foot in diameter.

The height of this series of kames where it is first met with, one to two miles above the mouth of Pine river, is about 40 feet above the lake, or 450 above the sea. At the water-shed between Pine River and Balch ponds it is about 600 feet above the sea. From this point the kames descend both to the south-east and north-west with the valleys, their slope along Pine river being 15 feet to a mile.

The accompanying plains along the lower part of Pine river are only 10 to 25 feet in height. At North Wakefield they are 60 feet above the river and pond; at East Wakefield depot they reach their greatest height, being 675 feet above the sea, or more than 100 feet above the lowest depression of the water-shed. The same belt of modified drift continues into Maine, forming extensive low plains in Acton and Shapleigh, with a height about 500 feet above the sea.

Review and Conclusions.

From the modified drift of Pine river, Ossipee lake, and Saco river, we learn the history of this part of New Hampshire in the Champlain period. After the ice-sheet had retreated from the coast, it seems for a long time to have still covered the Ossipee Lake basin, and the valley of Pine River and Balch ponds. The kames of this valley were deposited during this time in the channel of a glacial river, which carried forward its finer gravel and sand to form the plains that extend south-east from Balch pond. The coarse material and irregular surface of nearly all the modified drift along the upper part of Pine river indicate that masses of ice still remained at the time of its deposition.

After this, the ice-sheet disappeared from the broad low basin of Ossipee lake, and again for a long time had its terminal front at the border of the low area from which it had retreated. Its moraines fill the west and higher side of the narrow valley between Madison and Conway. These gradually change as we come to the centre of the valley to ordinary water-worn kames. This appears to have been the first outlet from the melting of the ice-sheet over the Saco valley and the south-east side of the White Mountains; and the material brought down was spread out to form the extensive sand and gravel plains about Ossipee lake and Six-mile pond. The comparatively small amount of levelly stratified drift associated with the kames in Madison and Conway makes it probable that the present outlet by Saco river was opened before the ice here had wholly disappeared, so that the later alluvium was carried by this river into Maine.

MODIFIED DRIFT IN THE BASIN OF PISCATAQUA RIVER.

Under this title are embraced nearly all our observations in Strafford and Rockingham counties. The streams which drain this district are united before reaching the ocean in Great bay and Piscataqua river.* Salmon Falls and Cochecho rivers are the largest of these, and have been the most thoroughly explored. Wide plains extend between these rivers in Rochester. Very interesting kames and kame-like plains occur about Dover, and are found frequently southward through the state. Isinglass, Bellamy, Oyster, and Lamprey rivers are known to be bordered in many places by intervals and low terraces and plains, but their modified drift has not been specially explored.

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* The topographic features of this basin are described in Vol. I, pp. 213–215, 302, and 313.

The valley of Exeter river contains large areas of modified drift. One of these diverges from this river at the south-east corner of Fremont, and extends to the south through Kingston, Newton, and Plaistow to Haverhill, Mass. This belt of modified drift reaches nearly fifteen miles, and is continuous from the Exeter to the Merrimack river. Along most of this distance it forms extensive plains. Several ponds in Kingston, which lie in depressions of these plains, are the sources of Powow river.

In Newington and Portsmouth a kame-like plain of gravel and sand is the highest land between Great bay and the Piscataqua river; but their shores, with the islands of this river below Portsmouth, are almost everywhere gently-sloping hills of till or ledge.

Marine shells and other organic remains have been found in the lower portions of this valley, showing that the ocean stood at a higher level when the modified drift in which they occur was deposited. The more particular description of this district will be taken up in the same order as in the foregoing summary.

Salmon Falls River. The source of this stream is East pond, which lies partly in Wakefield and partly in Acton, Me. It has an area of nearly three square miles, and a height about 500 feet above the sea, below which it can be drawn 18 feet, to supply the mills at Great Falls and Salmon Falls. This river and the Piscataqua form a part of the eastern boundary of New Hampshire. The descent below East pond is shown by the following heights, which are in feet above the sea: Horn pond, 479; at Milton Mills (fall), 440 to 416; at Milton Three Ponds dam, 412 to 400; above East Rochester, about 200; at Great Falls, 166 to 90; at Salmon Falls, 65 to 25; at South Berwick, 20 to tide-water. Salmon Falls and Cochecho rivers, along their lower three miles, and the Piscataqua river, which is the name applied below their junction, are affected by the tide, and flow with a strong current alternately towards and from the sea.

The north-west side of East pond is bordered by a low and partly swampy area of modified drift, which reaches a quarter to a half mile in width, enclosing Round pond. Except on this side, its shores are till or ledge. No examination has been made between this pond and Milton Mills. In the two miles from this village to Branch river, the modified drift rises in irregular slopes to a height of 20 or 30 feet.

Along Branch river the modified drift is well shown, forming swampy areas and terraces of sand or gravel 20 to 40 feet in height. Kames were noted in Wakefield a quarter of a mile west from Wolfeborough Junction, and at several other points southward to Union village. At one half mile to two miles south from this station they are finely displayed along the railroad, mostly on its west side. They are composed of coarse water-worn gravel, in ridges 25 to 40 feet high, with their trend generally north and south. These kames descend with the valley from about 575 to 475 feet above the sea.

The valley of Salmon Falls river in Milton contains three natural ponds, through two of which the river flows. The two south-west ponds lie near the east foot of Teneriffe mountain. They are bordered by kames on their west and south sides; and low, sandy plains extend between them and the North-east pond. They are all flowed to the same height by the dam at Milton Three Ponds village, which has been recently raised a few feet, overflowing a large meadow above North-east pond, and holding the river level six miles, or to within a half mile of Milton Mills. Below this dam the river descends about 200 feet in the next three miles, its channel lying between ledges or steep slopes of till.

The next modified drift is in the north part of Rochester (Plate VI, p. 146), where for a distance of two miles it occupies the entire area a mile and a half wide between Salmon Falls and Cochecho rivers. This tract is crossed by the Portsmouth, Great Falls & Conway Railroad. It consists of sandy plains, 25 to 40 feet above the river, or of extensive swamps and peat-bogs. The latter were scantily filled with modified drift, while it was more abundantly supplied on all sides, preventing drainage. Salmon Falls river here turns to the south-east. A straight course would carry it southward across this area, bringing it to a junction with the Cochecho at Rochester. In the Champlain period the highest floods of these rivers were united here, and nearly all the modified drift which they brought down was deposited in these plains.

At East Rochester a narrow belt of alluvium, from 20 to 30 feet high, borders the river. In the north part of Somersworth, sand and ordinary gravel extend from the river to the railroad and Cole's pond. These deposits lie in irregular slopes, nowhere presenting the usual level terraces. Thence very coarse kame-like gravel, spread out in level plains, extends southward, and forms the water-shed west of this river to Willand pond. In the next four miles to Salmon Falls, east of these kame-like plains, the valley of the river consists of till or ledge.

Below Salmon Falls the river has excavated its channel between prominent terraces, upon which the villages of South Berwick and Rollinsford are built. Their height is nearly the same at both sides, being about 80 feet above the river, or 100 feet above the sea. The same terrace-plain extends west to Rollinsford junction, where its height is 115 feet above the sea. The last mile and a half of this river is bordered on both sides by level plains about 40 feet in height. On the west these are a half mile wide, terminating in Rollinsford point.

Cochecho River. The water-shed between Winnipiseogee lake and this river is composed of modified drift (p. 130), which is very scanty or wanting along the next four miles to Farmington. Three streams, which are the head waters of this river, have here brought down large amounts of gravel and sand, forming the low and partly level area west of Farmington village. Below this place the modified drift, lying principally in kames, or irregular mounds and ridges, is continuous on both sides of the river, being one half to three fourths of a mile wide for five miles, beyond which it expands into the extensive plains of Rochester. These mounds and ridges rise from 20 to 30 feet above the intervening hollows, reaching a height about 50 feet above the river. Their material is coarse, water-worn gravel, with occasional layers of sand; and sections usually show an anticlinal or arched stratification. A half mile east of Farmington these kames enclose numerous bowl-shaped depressions, some of which contain small ponds. This part of the Cochecho valley is bordered on both sides by hills, which rise 300 to 400 feet above the river.

Two and a half miles above Rochester the area of modified drift widens on the east, reaching to Salmon Falls river (Plate VI, p. 146). Thence level, sandy plains, in many places underlaid by clay, extend along the Cochecho eight miles. The coarse kame-like gravel continues on the west side of the river nearly to Rochester; but the wide plains at this place consist wholly of fine alluvium, and no coarse deposits were seen farther south. Below Gonic these plains extend a mile wide to a distance of two miles west from the Cochecho, and, excepting isolated hills, they occupy the whole area between this and the Isinglass river.

The height of these plains at Rochester is 226 feet, and at Gonic 200 feet above the sea, being at each place about 30 feet above the river. Southward, the stream falls more rapidly than the plains, lying 75 feet below them in the south part of Rochester.

These deposits terminate near the mouth of Isinglass river; and the next four miles of the Cochecho valley are destitute of modified drift, which next occurs a fourth of a mile above the city of Dover. The river has here cut through the ridge of a kame which extends from the kame-like plain of Willand pond to that of Pine Hill cemetery. These were deposited by glacial streams, while the ice-sheet still remained unmelted on both sides. After the ice had disappeared, Cochecho river brought down the alluvial plain, composed of clay overlain by sand, on which the north part of the city is built. The south part of this plain has been excavated by the river, leaving the rest in the form of a terrace. Its height is 70 feet above tide-water, which extends to its foot at Dover landing. East of the city the river is again bordered by slopes of till or ledge.

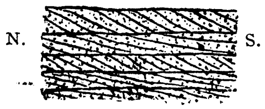

Fig. 37.—OBLIQUELY STRATIFIED SAND, ROCHESTER.
Scale, 1 inch=10 feet.

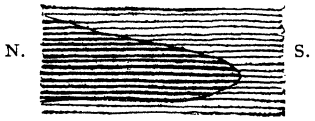

Fig. 38.—SECTION IN CLAY, ROCHESTER.
Scale, 1 inch=10 feet.

Beds of clay are worked for brick-making a half mile south from the Rochester depot, on the east side of the railroad, and a half mile farther south on the west side of Cochecho river. At the former brick-yard the clay is overlain by 5 to 8 feet of sand, which occurs principally in layers separated by nearly level lines, as shown in Fig. 37, but obliquely laminated with varying southward dip. About 15 feet of clay is exposed here, the upper part being *gray*, and most of the lower part *blue*, definitely separated from each other. The section shown in Fig. 38 was observed near the south end of this brick-yard. A mass of uniformly blue clay occupies a wedge-shaped space in the midst of gray clay. No difference, except that of color, could be seen; and the lines of stratification are plainly continuous through both.

At the second brick-yard 3 feet of sand overlies 15 feet of clay, which rests on a ledge. The upper part of this bed is compact gray clay, inclined to break into small fragments, the sides of which are stained with iron-rust; its lower portion is tenacious, and bluish gray in color.

Near Gonic the stratum is worked at four places, all on the east side of the river. Here the surface is 1 to 4 feet of sand. Next follows 10 to 15 feet of gray clay; this changes abruptly to blue clay, which is several feet thick, and extends below the excavations.

The brick-yard at Dover landing shows the following deposits, separated by definite lines: Sand at the top, 8 feet; gray clay, 12 feet; blue clay, 15 feet. A brick-yard beside the Piscataqua river, half a mile north from Dover point, shows 30 feet of clay,—its upper portion gray and its lower portion blue. The brick-yards on the south-west side of this point expose only the gray clay, which is about 15 feet thick, overlain by 2 or 3 feet of sand. We find here the features which usually mark the gray clay. Near the top it is free from sand, and is hard and compact, not showing its stratification, but breaking into small angular pieces, which are separated by films of iron-rust. In its lower part it shows lines of stratification, and sometimes contains sandy layers. Through the whole deposit pebbles up to six inches or one foot in diameter are rarely found. A well at one of these yards showed the bottom of this gray clay interstratified with sand and gravel, beneath which was blue clay.

The brick-yards along the Boston & Maine Railroad are similar to the foregoing. Half-way between the stations of Exeter and East Kingston beds of clay are found in kame-like banks, 20 to 30 feet in height, at both sides of the railroad. The top of these deposits is a few feet of sand or fine gravel, irregularly bedded as if laid down by strong and conflicting currents. The clay is nearly level in its stratification, and has a depth of about 20 feet. It is principally gray, but changes gradually near the bottom into blue clay. Another brick-yard of the same kind is found a mile farther south. These seem to be isolated deposits, having been formed like the kames in hollows of the melting ice-sheet. They lie on the till, and can hardly be supposed to be remnants of any formerly level deposit. The beds of clay near Dover point may be of similar origin.

The clay worked at Plaistow is alluvial, and was deposited in the quiet water, held back by a barrier of kames. The order here is as follows: sand at the top, 5 to 10 feet; gray clay, about 10 feet; gradual transition from gray to blue clay, 3 feet; blue clay, 5 to 10 feet, underlain by sand.

Beds of gray and blue clay are also found in the high terraces of Merrimack river, and in the valley of Hudson river and Lake Champlain (see pp. 94 and 95). In Vermont, where they contain marine shells, they were called by C. H. Hitchcock *Champlain clays*, from which this name has been applied to the period in which the ice-sheet disappeared.

The height of these deposits of clay in Hooksett and Pembroke is about 300 feet above the sea; in Rochester, about 200; at Dover Landing and Point, 20 to 50; and in East Kingston and Plaistow, about 100.

The wide distribution and unvarying order of the gray and blue clay suggest that they have some special meaning, which it may be important to understand for the right interpretation of our other records in surface geology. To what conditions and causes do these clays owe their difference in color?* Without being able to explain this, we have presented our observations as fully and plainly as possible.

Kames and Kame-like Plains about Dover and southward. Near the coast from Dover to Newburyport are frequently found massive kame-like deposits, consisting of high plains or broadly rounded ridges of gravel and sand, which often form water-sheds between wide valleys 100 to 200 feet below. The absence in these valleys of the terraces which mark erosion through modified drift, shows that they were never filled with the same materials, and that these remarkable plains and ridges were deposited in their present isolated position, with wide areas of lower land at each side. How this took place we can only explain by referring the formation of these deposits to the same causes which produced the kames. The ice-sheet still remained unmelted upon each side at the time of their deposition, filling the valleys and wide areas of low land, over which this gravel and sand must otherwise have been spread by the current of the floods on which they were brought.

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*These clays were the most finely pulverized portion of the abraded material contained in the ice-sheet. Their iron, which is always present in such quantity as to give the burnt bricks a red color, was in the same state of combination as in the rocks before pulverization, principally in ferrous sulphides, silicates, and carbonates. This is its condition in the dark and often blue clayey paste of the lower till. Has the underlying blue clay been washed from the ice-sheet by glacial rivers, transported many miles, and deposited, without the separation and further oxidation of its iron, which would give the clay a gray, brown, or reddish color? and have these changes been partially effected in the overlying gray clay? Or, did these changes take place quite fully before deposition, to be followed by deoxidation through the agency of organic matter, as has been shown by Dawson to be true of the mud now being deposited in the Gulf of St. Lawrence? In either case, the conditions which produced difference in color between the lower and upper portions of the clay remain to be explained. The anomalous section shown in Fig. 38 adds to the difficulty of this question.

The most extensive of these plains occur about Willand and Barbadoes ponds, near Dover, and in Newington and the north-west part of Portsmouth. Broadly rounded deposits of the same class occur frequently in this district; and southward, along the sea-coast, they form the elevations on which the villages of Rye, North Hampton, and Hampton are built. A very interesting ridge of this kind extends from north-west to south-east through Newburyport.

Willand pond* is situated principally in Somersworth, two and a half miles from the city hall in Dover. Its area is 84 acres, and its height above low tide in the Cochecho is 192 feet, as determined by survey of Hon. James A. Weston and Joseph B. Sawyer, made in 1871, in reference to supplying the city of Dover with water.† Their report says of this pond:

"It has no visible inlet worthy of consideration, and at ordinary stages it has no visible outlet. The ordinary annual high-water mark was about two feet above its surface at the time the survey was made. It appears that when the pond reaches this height, the surplus water, if any there be, runs off through a piece of low, wet, bushy ground (called a heath), of some 10 to 15 acres in extent, which lies on the northern border of the pond,—the water finally escaping through a slight artificial channel or ditch into a brook, which is tributary to the Salmon Falls river.

"On all other sides the pond is bounded by a dry, gravelly plain, which is from 12 to 17 feet above low water, and which extends from a quarter to a half mile from the pond. This plain is bounded in most directions by lower plains and valleys having a retentive clayey soil, which, being lower than the surface of the pond, contribute nothing to its waters.

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*The plain about this pond, and the kame which extends thence to the south, are shown on Plate VI, p. 146.

†Other heights in Dover, measured in this survey, are the following, stated in feet above low tide in Cochecho river: Lower step of front door of city hall, 45; do. of American House, 73; summit on Franklin st., near Dr. Horne's, 86; corner of Locust and Silver sts., 98; first floor of Belknap school-house, 123; threshold of tool-house at Pine Hill cemetery, 152; highest point on Garrison hill, 297.

"On the contrary, there are several large springs on the borders of the lower plains, which are supplied from the body of sand constituting the plain above, and probably in some instances from the pond itself. On the side next the city the springs are about 41 feet lower than the pond, and are of such size that they supply the water for the Cochecho Aqueduct Co. It is probable that these springs are subterranean outlets for the water of the pond, and undoubtedly these and all the others drain some portions of the sandy plain surrounding the pond. * *

"How extensive the area is which furnishes water to the pond we have no reliable means of determining, because the water-courses and divides are hidden beneath the surface. It may be stated in a general way that the wells sunk into this plain indicate that the water-table rises towards the north and west, and falls towards the south and east."

In 1876 a water-pipe was laid from this pond to Dover, for which a ditch was dug 25 feet deep for a quarter of a mile through the bordering plain. This ditch (Fig. 39) showed the plain to consist of interstratified gravel and sand, the former predominating, and containing abundant pebbles, of all sizes up to a foot and a half in diameter. The whole appearance is kame-like, but the materials are nearly level in stratification. The layers of sand were from a few inches to two feet in thickness, but were short, not being apparently continuous over large areas. At some points only the coarse gravel was found, with no clear sand. No boulders were seen on the surface or in the excavation.

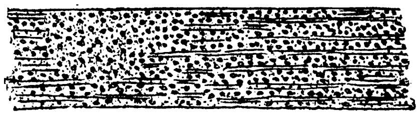

Fig. 39.—Section of Plain at Willand Pond, Somersworth.
Depth, 25 feet.

This plain about Willand pond is the highest land between Salmon Falls and Cochecho rivers, the descent to which is over uneven areas of ledge or till. The shores of the pond on all sides rise steeply to the level of the plain. Much of this escarpment appears to have resulted from the undermining action of waves. In other portions the gravel and sand were deposited with this slope, which, near the point where water is taken for the city of Dover, continues to a depth of 60 feet below the surface of the pond at ten rods from its shore. At that time the hollow which is now filled by the pond, and the wide valleys to the east and west, appear to have been occupied by portions of the departing ice-sheet.

On the south this plain descends 25 to 50 feet in an escarpment, below which the edge of the gravel and sand is overlain by a peculiar clayey stratum, which extends with an undulating or nearly level surface south-easterly to Garrison hill, and is also well shown south-west from Dover, between the city and Bellamy river. Its margin reaches 125 to 150 feet above the sea, and is marked by numerous springs. This deposit resembles the gray clay of the brick-yards in its color; its usually obscure stratification, which is, however, sometimes distinctly shown; its occasional division into small fragments, stained with iron-rust; and its containing infrequent pebbles from two or three inches to a foot in diameter. Except these isolated pebbles it is wholly a fine, clayey silt. On any exposed bank it is marked by many little channels, which have been formed by the rains, and are preserved through dry weather by the hardening of the surface.

The kame-like gravel of Willand pond extends three miles northward, to Cole's pond and the alluvial area of Salmon Falls river, near the east corner of Rochester. Southward it is narrowed to an ordinary kame, which is cut through by Cochecho river a quarter of a mile above the city of Dover. A very instructive section of it is shown by a railroad cut on the north side of this river (Fig. 40). The kame consists of gravel and sand, and is overlain on both sides by the widely spread gray clay. Numerous angular boulders, 2 to 5 feet in diameter, had been stranded on the north-west side of the kame before the deposition of the clay. An excavation between this section and the river exposed a boulder 8 feet in its greatest diameter and weighing 16 tons, with another two thirds as large, which were embedded in the kame.

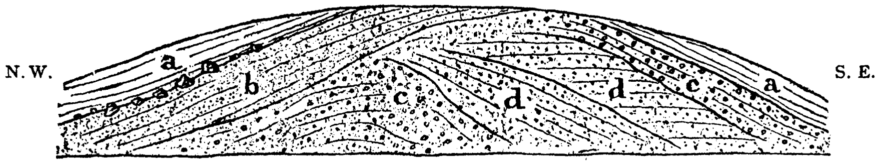

Fig. 40.—Section of Kame on Dover & Winnipiseogee Railroad, ½ mile north-west from Dover Station. Length, 300 feet; height, 40 feet.

The base of the section is about 40 feet above Cochecho river, or 75 feet above the sea.

a, a, gray clay; b, fine sand; c, c, coarse gravel containing pebbles from 6 inches to 1½ feet in diameter; d, d, fine gravel.

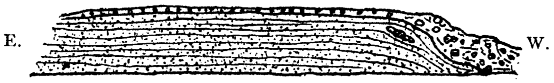

Fig. 41.—Sand overlain by Till, Fourth Street, west of Cochecho River, Dover.
Length of section, 250 feet; height, 30 feet; base of section is about 75 feet above the sea.

In the west part of the city this kame consists almost wholly of sand, and extends in a broad ridge to Pine Hill cemetery, being in some places overlain by till, but more frequently by gray clay. On the south side of Fourth street an excavation (Fig. 41) shows it to be horizontal in stratification, except at its sides, where it is obliquely bedded, conformably to its slope. Here its west side is overlain by the unstratified upper till, in which are numerous angular boulders 2 to 4 feet in diameter. This till also forms a layer two feet thick over the top of the sand, containing frequent rock-fragments of smaller size. Another section, showing 15 feet of irregularly bedded sand, overlain by a similar deposit of upper till, was observed a quarter of a mile farther south, at a height of about 140 feet above the sea. At these points it seems probable that the sand was deposited in an open glacial channel, bordered by overhanging walls of ice, from which the upper till fell upon the side and was partly strewn upon the surface of the kame.

A ditch for laying water-pipe on Silver street showed this sand deposit overlain by gray clay (Figs. 42, 43, and 44). The junction of the sand and clay was by a gradual transition, occupying one or two feet, and three or four feet of the clay next above was plainly stratified. The rest of the clay was very compact, with no evident lamination, breaking into iron-stained, angular pieces, and contained occasional pebbles. In the midst of this clay (Fig. 43) a horizontal sandy layer was very distinctly shown

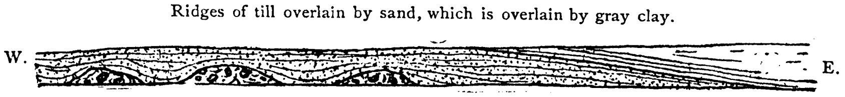
Ridges of till overlain by sand, which is overlain by gray clay.
W.
E.

Fig. 42.—Section along Silver Street, south of Riding Park, Dover.
200 feet long; 6 to 9 feet deep.

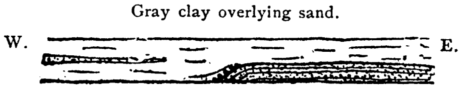

Fig. 43.—Same, 300 feet east of last; 100 feet long; 8 to 10 feet deep.

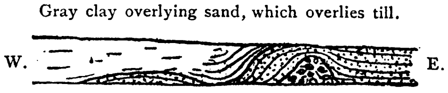

Fig. 44.—Same, 500 feet farther east; 100 feet long; 7 to 10 feet deep.

for a distance of 150 feet. Near its east end, iron-stained gravel and several stones a foot in diameter were found between the clay and the west edge of the underlying sand.

Eastward, these deposits lie in a kame-like ridge, a section of which (Fig. 45) shows one side of it to be wholly gray clay, while the other side is mainly sand; but their junction is concealed by the abutments of a bridge. The outer edge of the sand, however, is overlain by similar clay.

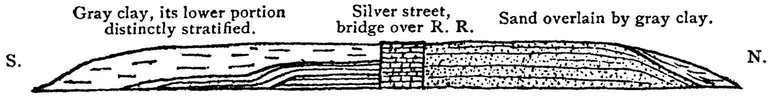
Gray clay, its lower portion distinctly stratified.
Silver street, bridge over R. R.
Sand overlain by gray clay.
S.
N.

Fig. 45.—Excavation for the Portsmouth & Dover Railroad, 1000 feet east from Fig. 44.

Length, about 500 feet; depth, 20 feet; top of section is about 100 feet above the sea.

Pine Hill cemetery, a half mile farther south-east, is a level plain of horizontally stratified sand, 150 feet above the sea. It is bounded on the north and west by escarpments, which descend steeply 30 feet. The deposition of this sand appears to have been confined here by walls of ice. On the south-east are ledgy hills which are somewhat higher, in whose hollows are low mounds or ridges of gravel and sand, one of which was observed to contain masses of till, one to three feet thick, full of angular boulders up to two feet in diameter (Fig. 46). These materials probably fell from the glacier upon the margin of ice at its foot, and when this was broken up, they were floated away on rafts, which at length melted, dropping their freight to be thus embedded in modified drift. The pebbles which we have mentioned as occurring here and there in the gray clay, were distributed in the same manner. This clay and its pebbles were deposited at a later date, following the withdrawal of the ice-sheet by which the earlier gravel and sand were confined in these kame-like plains.

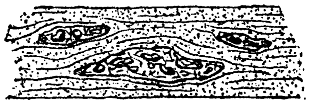

Fig. 46.—Section in a Kame south-east of Pine Hill Cemetery, Dover.

Scale, 1 inch=10 feet.

The sea in this period stood at a higher level than now; and the clay was probably a marine deposit brought down from the melting ice-sheet at the north-west. It is well shown in Dover, Madbury, Durham, and Newington, forming the surface of much of these towns, but not observed at a greater height than about 150 feet above the sea. On the borders of Great bay and Piscataqua river it seems not to exceed a height of 50 feet. A well near the Boston & Maine Railroad, about a mile west from Dover, passed through 20 feet of this compact, pebbly gray clay, below which was a water-bearing stratum of sand. A neighboring well showed 10 feet of similar gray clay; then 2 inches of clear sand; beyond which this clay continued 16 feet lower, and was underlain by 1½ feet of mud, apparently containing sticks and leaves, and lying upon ledge.

At the county farm, three miles north-west from Dover, and about 150 feet above the sea, a well showed 50 feet of this clay; which contained sandy layers, but otherwise was obscured in its stratification. Stones were frequently found, the largest of them weighing about 100 pounds. Below this was a stratum of gravel and sand, which seemed "like the bed of a stream," and yielded an abundance of water. This deposit lies upon till, which is exposed at forty rods to the north. On the west side of Cochecho river, at a bridge slightly farther distant to the north-west, is a kame that probably marks the mouth of the glacial river by which this marine delta was formed.*

Barbadoes pond, crossed by the line between Dover and Madbury, is surrounded by an elevated plain of gravel and sand,† about 175 feet above the sea, of the same kame-like origin with that about Willand pond. This plain is bounded by an escarpment 10 to 40 feet high. At its foot on the south-east are springs which supply the west part of the city of Dover.

Southward we find other extensive deposits of the same origin. On the south side of Bellamy river, for a mile and a half east from Madbury station, is a broad ridge of coarse water-worn gravel and sand of about the same height with the plain at Barbadoes pond, and 50 feet higher than the adjoining land, on any side. One mile south from Sawyer's mills in Dover, and in the same line with the foregoing, is a similar ridge two thirds of a mile long and about 150 feet above the sea. The ridge, about 125 feet in height, between Bellamy and Piscataqua rivers at one to two miles north from Dover point, is shown by wells to be the same interstratified gravel and sand. In this class, also, are, a ridge noted at the west line of Durham, half a mile south-west from Oyster river; the deposit, shown in Fig. 47, cut by the Nashua & Rochester Railroad at the divide between Oyster and Lamprey rivers; the gravel plain of Lee Hill village, 190 feet above the sea; and the plain of nearly the same height, two miles west from Newmarket, on the road to Wadley's Falls, composed of coarse gravel at the west, but of clear sand to a depth of 30 feet in its eastern portion.

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* A recent journey has brought to our notice an alluvial plain on the west side of the Cochecho, opposite to and lower than this delta. It was probably fluviatile, belonging to a later date when the ocean held a lower level. The rounded delta and the imperceptibly sloping plain show the contrast between deposition in deep and quiet water, as of a lake or arm of the sea, and that which takes place from the shallow floods of rivers.

† The extent of this deposit, and of others described at the south-east, may be seen on Plate VI, p. 146.

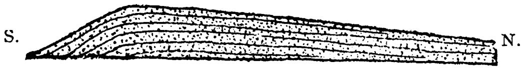

Fig. 47.—Section in sand near Wheelwright Pond, Lee.

Height, 30 feet. Base of section is about 150 feet above the sea.

One of these deposits near Newmarket Junction, composed mainly of sand with no rocks embedded in it, has its surface strewn with angular boulders, the largest of which are 10 feet in their greatest diameter, weighing 30 or 40 tons. The sand was deposited in the channel of a glacial river. When the ice on both sides and beneath it melted, this fell to the bottom of the shallow sea, which probably stood 150 feet above its present height. The boulders were then dropped on its surface by blocks or rafts of floating ice.

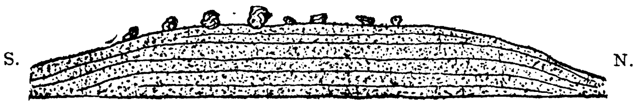

Fig. 48.—Section on Boston & Maine Railroad, ¼ mile north of Newmarket Junction.

Length, about 600 feet; height, 35 feet. Base of section is about 50 feet above the sea.

The academy in Greenland is built on a broadly rounded, kame-like ridge of gravel, which at a short distance to the south-west becomes a nearly level plain 40 or 50 rods wide, but still farther to the south-west is narrowed to a typical kame. The length of this deposit is a half mile. Its height is nearly 100 feet above the sea.

At a school-house half a mile south from the academy, we rise to a plain about 125 feet above the sea, which extends a mile to the south and south-east, descending with a gentle slope 25 to 40 feet in that distance. This plain forms the highest land between Winnicut river and Berry's brook. Its north-west portion is quite thickly strewn with boulders, the largest of which are 5 or 6 feet in diameter; and over nearly its whole extent these have been sufficiently abundant for walling the fields. Four wells, however, between the school-house and the Eastern depot, varying from 20 to 30 feet in depth, passed all the way through stratified gravel, sand, and blue clay. In three of these wells the upper portion was fine gravel or sand. One of them, a half mile south-east, and a cistern a quarter of a mile south from the school-house, showed at the top 10 feet of very coarse but water-worn gravel, which was underlain by clear sand.

Two thirds of a mile farther east, beyond the railroad and Berry's brook, a well at the house of L. & F. A. Berry (county map) encountered 10 feet of coarse gravel, below which were interstratified fine gravel, sand, and blue clay, extending 16 feet to ledge. Mussel shells which still retained their purple color, but were easily broken in pieces, were found in this well eighteen feet below the surface. Three fourths of a mile south from the school-house, a well at N. Norton's (county map) passed through 40 feet of coarse gravel containing pebbles up to 5 or 10 inches in diameter, with layers of sand. At a depth of about 25 feet in this well several white pine cones were found, and about 5 feet lower numerous mussel shells, both being well preserved and distinct. The two last wells are one and a quarter miles apart, each being at the surface about 100 feet above the sea.

The very thin covering of till and frequent scattered boulders which lie on the north-west portion of this plain, were probably in large part distributed by floating ice; but this appears to have taken place at a time when the ice-sheet paused in its retreat, and once more overspread areas from which it had withdrawn. Evidence of a reädvance of the ice-sheet was also afforded by a well in Stratham, a third of a mile east of Barker's hill. Here the surface was 5 feet of upper till, which also extended fully twenty rods on every side, containing boulders up to 6 or 8 feet in diameter, underlain by 21 feet of sand and fine gravel, the bottom of which was not reached. A hill in the north-west corner of North Hampton, which rises 75 to 100 feet above the lowland by which it is entirely surrounded, or about 150 feet above the sea, is covered to the top on its north side with very coarse glacial drift, containing abundant angular boulders of all sizes up to 10 feet in diameter; yet this hill is shown by wells to be principally composed of modified drift, a large part of which is clay.[*] On its south side the surface is gravel, with few boulders, none of which exceed 4 or 5 feet in diameter.

The last of these kame-like deposits which remains to be described within the limits of Piscataqua basin, is the extensive plain of Newington and the north-west part of Portsmouth. This is three miles long from north to south, and for most of this distance averages a mile in width, forming a plateau 60 to 100 feet above Great bay and Piscataqua river on each side. Outcropping ledges and scattered boulders are seen in many places upon its surface; but numerous wells show only modified drift to depths of 30 or 40 feet, being first coarse gravel, 3 to 10 feet in thickness, succeeded below by interstratified fine gravel and sand. The entire western edge of this deposit is a gently sloping escarpment, which descends 10 to 30 feet. On the north and east it rests mainly on ledges, but at one place falls in an abrupt slope more than 50 feet. A section at its base in the north part of Newington showed sand overlain by gray clay, as at Dover. Southward, near the Concord & Portsmouth Railroad, its surface is sand, obliquely stratified. Between this and the Eastern Railroad it is changed to a broad ridge, 25 to 30 feet high, composed mostly of pebbles six inches to a foot in diameter, packed as compactly as possible with no layers of sand. This gravel is finely exposed in an excavation, from which it is teamed two miles for repairing streets in Portsmouth. The deposit terminates south-east from the Eastern Railroad in a small plain of horizontally stratified sand.

Exeter River and the Plains at Kingston and southward. The principal part of Exeter village, and several square miles bordering Exeter river on the south and extending into Kensington, are alluvial sand and gray clay, 30 to 60 feet above the sea.

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[*] The following are sections of wells upon this hill, noted in order from north-west to south-east:

1. A well dug three years ago at C. C. Barton's, about 30 feet below the top of the hill, showed till on the surface, 4 feet; gray clay, plainly stratified and sandy in some layers, but containing occasional pebbles seldom more than 6 inches in diameter, 38 feet; clear sand, with water, 1 foot; blue clay, 9 feet, extending lower;—total depth, 52 feet.

2. The former well here, about 150 feet distant to the south-west and nearly the same in height, was through till, 4 feet; gray clay, as in new well, 4 feet; sand and fine gravel, 15 feet; gray clay, 27 feet;—total depth, 50 feet. The last eight feet were bored, and at the bottom the auger "fell," and a powerful flow of water came up.

3. At A. Wiggin's, near the top of the hill, a well 52 feet deep through unknown material becomes dry in summer, and was recently bored 12 feet lower through sand without striking ledge;—total depth, 64 feet.

4. At E. F. Wiggin's, perhaps 30 feet below the last place, the order was till containing boulders up to 500 pounds in weight, with layers of gravel and sand, 20 feet; interstratified fine gravel, sand, and clay, 20 feet; very compact gray clay, nearly free from rock fragments, 16 feet, underlain by quicksand with abundant water;—total depth, 56 feet.

5. A well dug two years ago at T. E. Marston's, about 20 feet lower than the last, passed through coarse water-worn gravel, with the largest stones 1½ feet in diameter, 8 feet; sand and fine gravel, 10 feet; gray clay, stratified and containing layers of sand, 20 feet;—total depth, 38 feet.

A map on Plate VI (p. 146) shows the belt of plains which extends south from this river to the Merrimack at Haverhill, Mass. At the north line of Kingston their height is about the same as that of Spruce swamp in the east part of Fremont, which is shown by the survey for the Nashua & Rochester Railroad to be 160 feet above the sea, or about 30 feet above Exeter river. Half of the township of Kingston is occupied by these sandy plains, which slope to a height of 125 feet above the sea at its south line. Numerous ponds, which are the sources of Powow river, mark where portions of the ice-sheet remained unmelted while the deposition of modified drift went on rapidly at each side. A large area of kames is indicated on the map in the northern part of Plaistow. Their southern portion consists of the ordinary water-worn gravel in short, steep ridges and mounds. At the north and north-west, these pass gradually into very coarse morainic débris, containing angular blocks of all sizes up to 10 feet in diameter, much of which is accumulated in low ridges like those of the kames. In Plaistow the plains continue their slope to about 90 feet above the sea. In Haverhill a large portion of the original deposit has been excavated by Little river; and its south end has been partly undermined by the Merrimack, on whose north side it forms a conspicuous terrace west of the railroad bridge.

Fossils. Although it seems probable that the sea stood about 150 feet higher than now during the deposition of most of the modified drift in this basin, only very scanty relics of the life of this period have been found. A whale's vertebra, now in the museum of Dartmouth college, was discovered in Somersworth in 1843 by the caving in of a gravel bank, but no other bones were found. Several wells in the village of South Berwick show marine remains at a depth of about 30 feet in a stratum of fetid mud, which resembles that of the tide-flats, and frequently renders the water unfit for use, at least through a part of the year. The humerus, radius, and ulna of a seal, and shells of *Nucula Portlandica* (see foot-note on next page), are mentioned by Jackson from wells at this place, which are about 100 feet above the sea, the fossiliferous stratum having a height of about 70 feet. The surface here was three feet of sand, the whole depth below which was clay, the upper portion gray and the lower blue. A third of a mile to the south, near the landing, two wells at about 50 feet above the sea show 20 feet of gray and 10 feet of blue clay, succeeded by a layer of fetid mud with numerous clam and mussel shells 30 feet below the surface, or only 20 feet above the sea. Casts of clam and mussel shells were found in a brick-yard worked twenty years ago on the shores of Bellamy river, a half mile north-west from Dover point. They also occur in the brick-clay of Eliot on the east side of the Piscataqua.

Shells[*] of *Saxicava rugosa*, *Mytilus edulis*, *Sanguinolaria*, and *Astarte castanea* were found at several places in Kittery within 30 feet above the sea by Mr. John L. Hayes. He also discovered *Nucula Portlandica*[*] and *Sanguinolaria*[*] in Portsmouth near Wibird's hill. The shells at this place were 15 feet below the surface and 30 feet above high tide, in blue plastic clay. Mussel shells are reported at two localities in Greenland (p. 163); but farther to the south no fossils appear to have been discovered within the limits of this state, although there is considerable modified drift which was probably deposited beneath the sea. The shells found in Portsmouth and South Berwick show that an arctic climate prevailed during the deposition of the beds in which they occur; but the presence of *Astarte castanea* at Kittery is proof that the ocean became as warm as now before it sank to its present level.

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[*] Jackson's *Final Report on Geology of New Hampshire*, pp. 94, 121, and 281.

The shells here mentioned are all species now living. One of them is confined to arctic seas; of the rest, all but one are circumpolar, extending south to our latitude, while one has its northern limit at Nova Scotia, and is most abundant southward. Their synonyms and range, fossil and living, are as follows:

Nucula Portlandica, Hitchcock; *Leda truncata*, Brown; *Leda arctica* and *Portlandia glacialis*, Gray; *Yoldia arctica*, Sars (but not of Möller and Mörch). This shell gives its name to the *Leda clay* of Canada. Fossil in New Hampshire, Maine, New Brunswick, Province of Quebec, Labrador, Norway, and Scotland. Portsmouth, N. H., is the most southern locality at which it has been found. Now living only in arctic seas; found at Spitzbergen in depths from five to thirty fathoms.

Saxicava rugosa, Linn.; *S. arctica*, Deshays. Variable, having been described under five genera and fifteen species. This shell gives its name to the *Saxicava sand* of Canada. Fossil from New England to Labrador and in Europe; var. *distorta*, Say, is found in the Miocene of Maryland. Now living in arctic seas, and abundant southward to Cape Cod, and less common to Georgia; also extending south to the same latitude on the Pacific coast of America and in Europe. It occurs from low-water mark to a depth of fifty fathoms.

Mytilus edulis, Linn. Common mussel. Fossil from New England to Greenland and in Europe. Now living in arctic seas, extending south in the Atlantic to North Carolina and the Mediterranean sea, in the Pacific to China and San Francisco. Littoral to fifty fathoms.

Sanguinolaria (obsolete); *Macoma*, Leach. Two species of this genus, *Macoma Grœnlandica*, Beck (*M. fragilis*, Adams), and *Macoma sabulosa*, Mörch (*M. calcarea*, Adams), are common as fossils from New England to Labrador and Greenland, and the latter also in Europe. Both are now living on our coast from the Arctic ocean to Long Island; the latter is also found in northern Europe, and extends south on the coast of Asia to Japan.

Astarte castanea, Say. Fossil at Nantucket and Point Shirley, Mass., and at Kittery, Me. Now living from New Jersey to Nova Scotia; common as far north as Massachusetts bay. Abundant in Provincetown harbor at low-water mark, but more frequently occurring at depths from five to fifteen fathoms.

Mya arenaria, Linn. Long clam; the common clam of our coast north from Cape Cod. (*Venus mercenaria*, the round clam, or quahog, is the common species south from New York.) Fossil from South Carolina to Greenland, in Europe, and in the Miocene of Virginia. Now living from the Arctic ocean to South Carolina,—very abundant as far south as New Jersey; also extending south to France and China. Between high and low tide, and thence to forty fathoms.

KAMES IN THE SOUTH PART OF ROCKINGHAM COUNTY AND IN NORTH-EASTERN MASSACHUSETTS.

This district contains very interesting and instructive series of kames, which differ from those described along the Connecticut and Merrimack rivers, and in the basin of Ossipee lake. It will be remembered that those series lie along the middle and lowest portion of valleys. The series of kames now to be considered do not follow the present water-courses, but run directly across the Merrimack and other rivers, which here have no well marked valleys, being not much lower than the hollows between the hills on either side. Occupying these hollows or lying against the side of the hills, the kames extend long distances in a somewhat devious, but for the whole series, quite straight course, which is about half-way between south and south-east.

Rev. George F. Wright, of Andover, Mass., has given much attention to the surface geology of this district, and has kindly supplied the following description of these kames:*

A formation of gravel, known at Andover as "Indian Ridge," has long been familiar to the citizens, and has been remarked upon frequently by tourists and geologists. We could not improve the description of the main features of similar formations given by Dr. Edward Hitchcock in 1842.† He writes,—"Our moraines form ridges and hills of almost every possible shape. It is not common to find straight ridges for a considerable distance. But the most common and most remarkable aspect assumed by these elevations is that of a collection of tortuous ridges and rounded and even conical hills, with corresponding depressions between them. These depressions are not valleys which might have been produced by running water, but mere holes, not unfrequently occupied by a pond."

By reference to Map 1, Plate IV, the characteristics of this formation may easily be apprehended. At the flax mills near Andover depot, a dam raises the Shawshin river 14 feet. Measuring from the river-bed below the dam, the ascent to the peat-bog, *o*, at the base of the east ridge, is 41 feet. Taking this bog as a level, the heights of the successive ridges,—East ridge, Indian, and West,—at the points *a*, *b*, and *c*, are 41 feet, 49 feet, and 71 feet. The point *c*, however, is in a characteristic depression of the ridge. On either side of it, north and south, prominences project 20 feet higher, making them 91 feet above the base assumed at *o*, and 132 feet above the river, or 182 feet above the sea.

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* For some further particulars and facts bearing on the origin of these series of kames, see a paper by Rev. Mr. Wright in *Proceedings of the Boston Society of Natural History*, vol. xix, pp. 47-63.

† *Transactions of the Association of American Geologists and Naturalists.*

Branches not adequately indicated on the map run off at various points and form enclosed basins, which have no outlet except as channels have been cut through the loose material of the ridges, either by natural or artificial means. Quite an extensive body of water was included, till long after the settlement of the town, in an enclosure between *b* and *c*. It has been drained, partly by a channel of its own formation and partly by artificial means, and is now occupied by a muck swamp, which is 20 or 30 feet deep. A trigonometrical section of the west ridge, near the point *c*, gives the height above this swamp 61 feet, with a base of 250 feet. The rate of descent from the apex at this point to the base is therefore one foot in two.

A few rods east of the point *o* there are irregular remnants of ridges of the same general character with the others, running south-east across the Shawshin river and Boston & Maine Railroad. East of this railroad it is apparently pushed into a great number of irregular prominences enclosing numerous bowl-shaped basins, one of which, of oblong shape and about fifteen feet deep, is at the very summit, the rim of which rises to a height of about 100 feet above the river. A mile south, at Pomp's pond, and partially connected by intervening ridges, is a similar cluster of rounded hills and enclosed basins, surmounted by a sharp peak of still greater height.

We should also observe that clusters, or ganglions, of such irregular ridges, encircling bowl-like reservoirs and rising into sharp peaks, occur at frequent intervals along the whole belt of the formation we are describing. Frequently, as a ridge is suddenly pushed up into a pinnacle, it will put out a spur, returning to itself and forming a closed basin at or near its top.

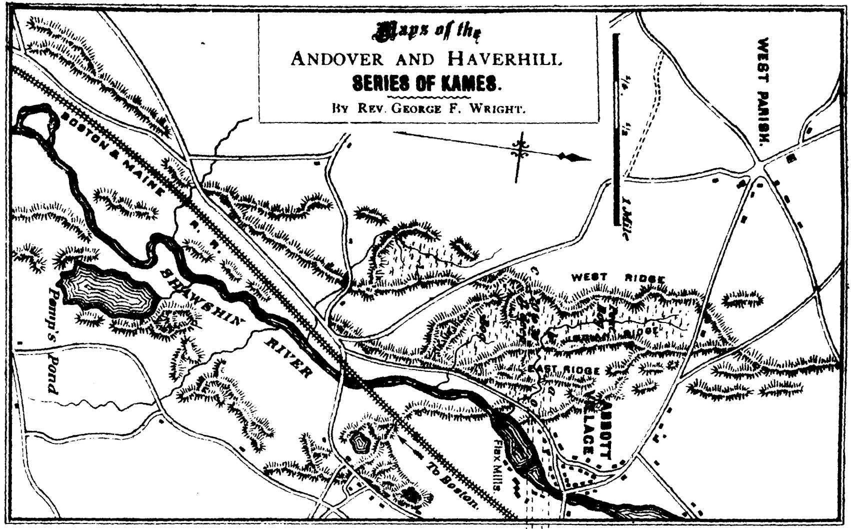
These ridges are ordinarily composed of sand, gravel, and pebbles, the latter from a few inches to two or three feet through, sometimes irregularly stratified, the coarse material being as likely to abound near the top as at the bottom; at other times, 10 or 15 feet or more in thickness will give no signs of stratification whatever. The top of the ridge is usually just wide enough for a foot-path; and pebbles a foot or two in diameter dot its course at frequent intervals. Usually, also, the base of the ridge is partially hid by subsequent accumulation of stratified sand and fine gravel, or by peat-bogs.

Another point of importance is, that the fragments of rock in the ridges are nearly all somewhat rounded and apparently water-worn, though it is evident that they have not all been subjected to the same amount of attrition. I have searched in vain among the débris of the formation for scratched stones, though striated stones are found in abundance near the surface in the immediate vicinity. Furthermore, the pebbles are not of local origin. Merrimack slate abounds, as does a porphyritic gneiss, whose position is well determined in central New Hampshire. In Topsfield, a portion of the pebbles are clearly from ledges only a few miles to the north-west.

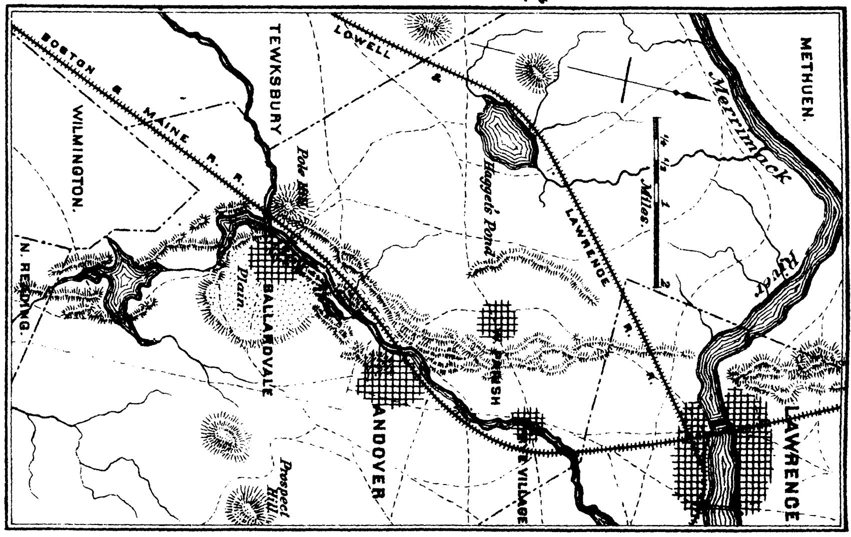
The formation does not lie at a uniform altitude above the sea, but rises over hills

Plate VII.

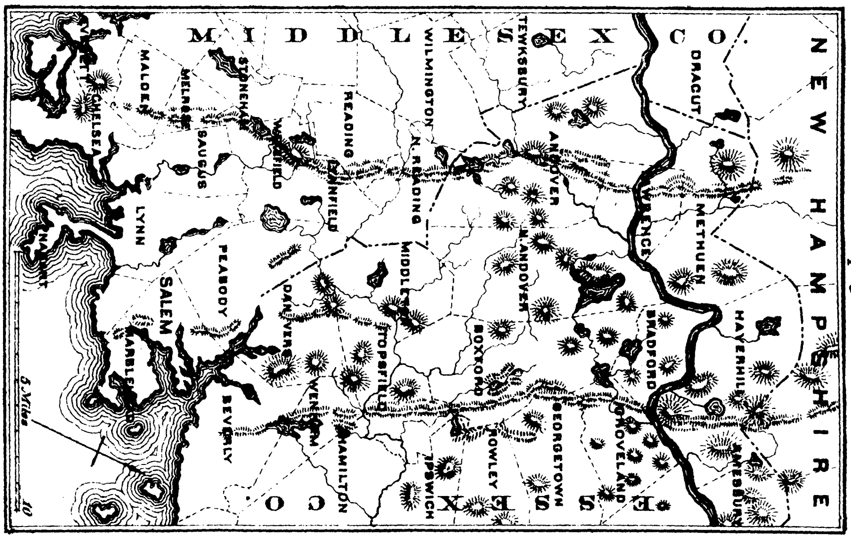
Map 1.



Map 2.



Map 3.



HELIOTYPE

and descends into river valleys in a certain apparent independence of the natural configuration of the country. The land, however, though undulating and somewhat broken, nowhere in this part of Massachusetts rises more than 300 or 400 feet above tide-water; and even these heights are reached only by peculiar accumulations of unmodified drift or till, which here forms massive rounded hills. The gravel ridges plainly belong to the superficial deposit, since they everywhere overlie the ground-moraine or till. They rest upon the flanks of these hills at Lawrence near the reservoir; at Ballard Vale, on Pole hill; at Wakefield, near the rattan works; in the north-east part of Middleton; and on the north bank of the Merrimack in Haverhill, opposite to and a little below Groveland.

Sometimes the ridges disappear in a sandy plain, in which case, however, there are usually bowl-shaped depressions in the plain along the line of general direction. This is noticeable east of Ballard Vale. These depressions are frequent in Kingston, N. H., near Great pond. But the most remarkable instance is near the cemetery in Marblehead, a half mile south-east from the lead mills in Salem. Here is a cluster of depressions within a depression. The outer rim has a north-to-south diameter of 605 feet, and an east-to-west diameter of 735 feet. A hollow at the south side descends to the tide-level, with a depth of 60 feet and an east-to-west diameter at the top of 360 feet. A similar though shallower hollow occurs at the north-west side. Numerous minor depressions intervene. The material of these circular ridges is partly of local origin, and partly not. Plant them upon higher ground, and they would be called the reticulated portion of a kame. Many lakelets are but these depressions full of water.

These ridges have been found in two well defined series, as shown in Map 3, Plate VII. The westernmost or *Andover series* may be represented in Rockingham county by kames observed near the Manchester & Lawrence Railroad, north-west from Wilson's crossing in Londonderry, near West Derry station, and at a point a mile and a half farther south on the west side of the railroad; also near Goss pond in the south-east part of Londonderry, where there are bowl-shaped depressions, and thence southward to West Windham station on the Nashua & Rochester Railroad; also near a granite quarry a half mile west from Salem Depot.

In Massachusetts this series extends through Methuen, Lawrence, Andover, North Reading, Reading, Lynnfield, Wakefield, and Melrose, terminating near the south end of Prospect hill in Malden. It is continuous from Messer's crossing and Mystic pond in Methuen to the pumping-station of the Lawrence water-works, being well shown on the hillside south-east of the reservoir. On the low land near Spicket river these ridges show stratification; but higher up, as north-west of the Catholic cemetery, they are for the most part unstratified. Bowl-shaped depressions abound.

This series is finely developed near Andover, as shown in Maps 1 and 2, forming the banks of Pomp's, Foster's, and Martin's ponds. Numerous sections of these ridges show the central portion unstratified, the pebbles of large size being in and resting on the clay, loam, and unwashed sand; but sometimes we find stratified material under an unstratified mass, or pockets of partly stratified material in the unstratified.

In North Reading and Reading this series winds its way through extensive swamps, intersected by Ipswich river; in Wakefield much of its material has been removed by human agencies; in Melrose it is characterized by a plain with depressions. Its length in Massachusetts is about twenty-five miles.

The *Haverhill series* of kames is nearly parallel with the preceding, and about seven miles distant. It appears in the north-east part of Auburn, near Eaton's mills; in Chester, near Asa Wilson's; in Sandown, with extensive sandy plains and numerous ponds; and in East Hampstead, where the ridges are well defined, extending to the west side of Mt. Misery at the north line of Plaistow. A mile south-east from Mt. Misery the kames occupy a large area, and are thence continuous through Plaistow and the east part of Haverhill. They are well shown in Haverhill, near the old Whittier house; near the East Parish church; and near Burns's mill. At the Whittier house they seem to have been composed of coarse pebbles in contact with each other, sand having subsequently sifted into the interstices.

In Groveland they are partly covered with alluvium north of the depot. Rock pond in Georgetown is bordered by a spur of this series, and divisions of it extend south from both sides of Bald Pate hill. Wood pond and Four-mile pond in Boxford, Pritchard's pond in Ipswich and Topsfield, and Muddy pond, Cedar pond, and Wenham lake in Wenham and Beverly, are surrounded by these deposits, which extend nearly to Beverly Cove. This series is not less than forty miles in extent.

Between the southern portions of these series of kames an intermediate one appears in Map 3, running from Topsfield with some interruptions to the depressions, or "dungeons," which we have described in Marblehead. Near Danversport these kames are stratified, but farther north two or three fresh sections show no stratification.

Kames also occur in a series still farther to the east, though perhaps less closely connected with one another than the foregoing. They are well developed in the west part of Spruce swamp in Fremont, where one of these ridges is occupied by a road. Kames and bowl-shaped depressions border Great and Country ponds in Kingston. In the east part of Newton and the south-west corner of South Hampton a large area is covered by reticulated ridges, 20 to 60 feet in height, and containing boulders 2 to 4 feet in diameter. The long arm of Kimball pond in Amesbury is bordered on its north-east side by the continuation of this series, which is here a single ridge of ordinary gravel 20 to 40 feet high.

MODIFIED DRIFT ALONG THE SEA-COAST.

The oldest and most prominent deposits of modified drift near our coast are kame-like hills, elevated plains, and broad ridges, composed of gravel, sand, and clay, the description of which is here continued from page 164. The gently-sloping hill on which Rye village is situated, nearly 100 feet above the sea, is mainly stratified gravel from 25 to 40 feet in depth. It is coarse for the first ten feet, with the largest pebbles a foot in diameter; below, it is fine, but has little clear sand.* Breakfast hill, about 150 feet above the sea, and the plain about 50 feet lower, which extends southward to the first railroad crossing in North Hampton, are composed of coarse gravel and sand. Thence similar deposits, 100 to 125 feet above the sea, extend in nearly level plains south-west to North Hampton village, forming the water-shed between Winnicut river and the ocean. They are bounded in many places by escarpments which descend steeply 25 to 50 feet; and a hollow, about an acre in extent and 50 feet deep, is half filled by Knowles pond. This formation continues southward with nearly the same height to Hampton village, where it terminates, falling in gentle slopes towards the sea.

Nine miles farther south, part of the city of Newburyport is built on a broadly rounded ridge of gravel and sand, which, like the foregoing deposits, probably had a similar origin with the narrow and steep ridges of the kames, having been bounded by portions of the melting ice-sheet. The series of kames noticed by Rev. Mr. Wright in Newton and Amesbury may be continuous south-east to the Newburyport ridge. So far as traced, this deposit appears first in the south part of Amesbury. It has been cut through by Merrimack river, and on its opposite side rises to a height of about 150 feet in Moulton's hill. A quarter of a mile farther to the south-east it is depressed to 75 feet, and shows the sharp ridges and knolls of typical kames. From this point it extends, with a nearly uniform height of about 100 feet, along High street to the middle of the city, and thence continues on the south-west side of this street to the Upper Green. Here it is interrupted for a little distance, beyond which it lies on the north-east side of this street, extending to within a half mile of Old Town hill. It is thus at least six miles long. No other high deposits of modified drift are found in this vicinity; and wide areas of lowland lie on both sides. Excavations in the north-west part of the city show the ridge there to be composed mainly of water-worn gravel, with the largest pebbles about a foot in diameter. A railroad cut, known as March's hill, two miles farther south-east, has only occasional layers of gravel, with the largest pebbles six inches in diameter, very irregularly stratified with sand, which is here four fifths of the whole deposit. The depth of modified drift forming the ridge is shown by wells to be from 50 to 90 feet.

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* The character of these deposits will be seen from the following sections of wells, 1 to 1½ miles south-west from Rye village, on the water-shed south of Berry's brook, and about 100 feet above the sea:

1. At J. Philbrick's (county map), said to be the deepest well in Rye, coarse gravel, 25 feet; sandy, gray clay, very compact, free from pebbles, 28 feet;—total depth, 53 feet. The only rock found in the clay was an angular block weighing about 200 pounds, 40 feet below the surface.

2. Near L. Brown's, coarse gravel, 8 feet; sand, 8 inches; coarse gravel, 6 feet; very coarse gravel, 10 feet, much of it composed of rounded rocks of nearly uniform size, about a foot in diameter, with scarcely any earth, so that "one could look down among the pebbles;" ordinary gravel, with layers of sand, 20 feet, resting on ledge;—total depth, 45 feet.

3. At R. Shapley's, coarse gravel, 10 feet; fine white sand, 15 feet, resting on till or ledge. Several other wells in this neighborbood, 30 to 40 feet in depth, encountered nothing but stratified gravel, sand, or clay.

Portions of Seabrook and Salisbury are sandy plains, 25 to 50 feet above the sea. These are probably marine beds, deposited in a considerable depth of water, but they are not known to contain organic remains.

The most recent deposits of modified drift are the *beaches and salt marshes* bordering the ocean. Along much of our coast, at a distance varying from a quarter of a mile to one mile or more beyond the natural shore of hard land,—that is, of ledge, till, or ordinary modified drift,—we find a beach-ridge of quartzose sand, which becomes gravel or shingle near rocky shores. This ridge of loose material has been heaped up by the waves nearly to the highest point reached by them at high tide during storms; and when it is composed of sand, the wind piles it still higher in irregular hills, mounds, and ridges, which are constantly changing in form. The beach-ridge of Plum island, at the mouth of Merrimack river, is thus blown into dunes 50 feet high. On the side away from the sea, this formation slopes somewhat steeply to the solid bottom, 10 to 40 feet below the sea-level; towards the sea, it often slopes away very gently, with a wide area of hard sand between the lines of high and low tide. For a quarter of a mile out from these beaches the water is shallow, and the waves break upon shifting banks of sand.

The area from the beach to where the land rises above the reach of the sea is usually occupied by salt marsh, which has a level surface two or three feet below the highest tides. This is composed of fine, clayey mud, brought in and deposited by the tide, which cuts channels for its flow and ebb. None of our forest trees can endure salt water; and the marshes are left to a rank growth of the grasses and sedges peculiar to the sea-coast. On the south side of Long Island, and thence southward, the beach is frequently divided from the shore by extensive sounds or shallow bays, which are partly filled with salt marsh.

The shores of Rye and North Hampton are principally till or ledge, with frequent beaches and marshes of small extent. About forty rods south from the United States life-saving station and cable station, near Straw's Point, the stumps of a submerged forest are exposed at low tide on the north end of Jenness's beach. In July, 1877, more than seventy-five stumps could be counted here, the largest of them two feet in diameter and three feet high. Numerous specimens of the wood then obtained seemed to be all alike, and are pronounced by Mr. William F. Flint to be white cedar (*Cupressus thyoides*). Other stumps farther out projected above the water, and they are said to extend out to a depth five feet below the lowest tide. They have not been so well exposed for several years before this, and in 1874, when the cable was laid, they were not seen, being covered with sand. The most probable explanation here is that given by Mr. John L. Hayes,* who supposes that the forest grew at a higher level on the surface of a peaty swamp, which was protected from the sea by a beach. The beach has since been driven inland, and the mud of the swamp has been washed away; but the trees were interlaced by their roots, and all sank together, so that they are now covered by the sea. Stumps occur in salt marshes near the head of Sagamore creek, on Little river, and in Hampton, probably where swamps have become more compact and settled within reach of the tide. If any change in the relative height of land and sea is now going forward on our coast, it would appear to be a very slow submergence of the land, not amounting to a foot in a hundred years.

Little and Great Boar's Head are bluffs of till, about 50 feet in height, which are being undermined by the waves. South from the latter point, a beach-ridge extends 15 miles, broken only by Hampton and Merrimack rivers, and bordered all the way on the west by a salt marsh, which averages a mile in width. The beaches of Hampton, Salisbury, and Plum island are on its east side. A large part of these deposits was probably carried out to sea by the Merrimack river, and then turned back by waves and tide.

It has been shown that the sea stood in the Champlain period 150 feet higher than now, from which level it sank to its present height, or lower; but no well marked beach-ridges have been discovered inland.

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* Letter in Jackson's *Final Report on Geology of New Hampshire*, pp. 280 and 281. A valuable essay was published by Mr. Hayes in the *Boston Journal of Natural History*, vol. iv, 1844, on the "Probable Influence of Icebergs upon Drift."

REVIEW OF THE CHAMPLAIN AND TERRACE PERIODS IN NEW HAMPSHIRE.

The *Champlain period* embraces the time occupied by the final melting of the great ice-sheet. At first its nearly level surface of pure ice lay above our highest mountain summits. As the melting advanced, it was moulded into basins and valleys, which, near the terminal front of the ice, coincided nearly with the contour of the land. At last the surface of the ice became covered with the abraded material which had been contained in its mass. A large part of this material was washed away by its streams, to be deposited in the modified forms of kames,[*] kame-like plains, and valley drift. Through the whole of every summer during the Champlain period, our rivers were swollen as we see them now in the floods of spring, but they were laden with far greater amounts of alluvium. The valleys were thus gradually filled with modified drift, which took the same slope with the descending current. In some instances (pp. 65, and 116–119) there is evidence that the ice-sheet in its departure was for some time a barrier, holding back lakes where there are now empty valleys, sloping to the north or west. If the principal lines of drainage throughout the state had been in these directions, such lakes must have been frequently formed during the retreat of the ice towards the north-west. With these exceptions, the deposition of our valley drift appears to have taken place in the same manner that additions are made to bottom-lands by high floods at the present day.

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[*] Since writing the first part of this chapter, I have learned that, as early as in 1872, Prof. N. H. Winchell, state geologist of Minnesota, had been led by his observations of kames in Ohio and Minnesota to an opinion respecting their formation similar to that presented in pp. 12–14, which, when first announced in August, 1876, was supposed to be entirely new. (See citations below, under *Ohio* and *Minnesota*.)

For the benefit of those who may be interested in this subject, and may wish to see descriptions of these deposits elsewhere, we append the following list of authors who have treated, more or less fully, of kames:

Canada. Principal J. W. Dawson, *Notes on the Post-Pliocene Geology of Canada*, 1872, pp. 26, 40, 107, and 112; *Acadian Geology*, 1868, pp. 82 and 324. *Geological Survey of Canada; Report of Progress for* 1870–71, p. 349 (Robert Bell); *do. for* 1875–76, pp. 262 (G. M. Dawson) and 340 (Robert Bell).

Maine. Prof. C. H. Hitchcock, *Agriculture and Geology of Maine*, 1861, pp. 271–274; *do.*, 1862, pp. 388–391. Prof. L. Agassiz, *Atlantic Monthly, vol. xix*, February, 1867, pp. 213–215.

New Hampshire. Dr. Edward Hitchcock, *Transactions of the Association of American Geologists and Naturalists*, 1840–42, p. 198, Plate viii; also, *Smithsonian Contributions, vol. ix*, 1857, pp. 36 and 45. Warren Upham, *Proceedings of American Association for Advancement of Science, vol. xxv*, 1876, pp. 216–225.

Vermont. Prof. C. H. Hitchcock, in *Geology of Vermont, vol. i*, 1861, pp. 95, 102, 150–152, and 190.

Massachusetts. Dr. Edward Hitchcock, *Geology of Massachusetts*, 1841, pp. 356 (Figs. 62 and 65) and 366–370; *Transactions of the Association of American Geologists and Naturalists*, 1840–42, pp. 190–203, and Plates viii and ix; and *Smithsonian Contributions, vol. ix*, 1857, p. 44 (lowest paragraph). Rev. George F. Wright, *Proceedings of Boston Society of Natural History, vol. xix*, 1876, pp. 47–63.

Connecticut. Prof. James D. Dana, *Transactions of the Connecticut Academy of Arts and Sciences, vol. ii*, 1870, pp. 70 and 71.

New York. *Geology of New York, Second District*, E. Emmons, 1842, pp. 186, 323, 333, and 364; *do., Third District*, L. Vanuxem, 1842, p. 247. In this and other states bordering the great lakes, ridges of sand and gravel are found, which must be distinguished from the kames, being apparently ancient beach-ridges, formed when these lakes were held at higher levels during the Champlain period. Their present outlet through the St. Lawrence valley was obstructed by the ice-sheet, which seems here to have retreated from south-west to north-east.

Ohio. Dr. J. S. Newberry, *Geology of Ohio, vol. ii*, 1874, pp. 7, and 41–46. Prof. N. H. Winchell, *Proceedings of American Association for Advancement of Science, vol. xxi*, 1872, p. 165.

Michigan. E. Desor, in Foster and Whitney's *Report on Geology of Lake Superior*, 1850, pp. 196 and 205; *do., part ii*, 1851, p. 258.

Minnesota. Prof. N. H. Winchell, *Geology of Minnesota, First Annual Report* (for 1872) p. 62, etc.; *Report for* 1873, p. 194, etc.

Ireland. G. H. Kinahan, *Geological Magazine, new series, vol. i*, 1864, pp. 34, 89, and 189; *do., Decade ii, vol. ii*, 1875, pp. 86 and 87.

Scotland. James Geikie, *Great Ice Age*, 1874, American edition, pp. 209–237; *do., second edition, revised*; London: 1877, pp. 210–252.

Sweden. James Geikie, *Great Ice Age*, 1874, American edition, pp. 357–367; *do., second edition, revised*, pp. 407–416.

The modified drift, though extensive, constitutes only a part of the material which was contained in the ice-sheet. Probably more escaped erosion than was carried away by the glacial streams. When the ice was wholly melted, the part remaining fell upon the striated ledges and ground-moraine, being the loose upper till, with numerous angular boulders, which forms the surface generally throughout the state. Outcropping ledges, however, are frequent; and both the kames and valley drift rest upon the upper till.

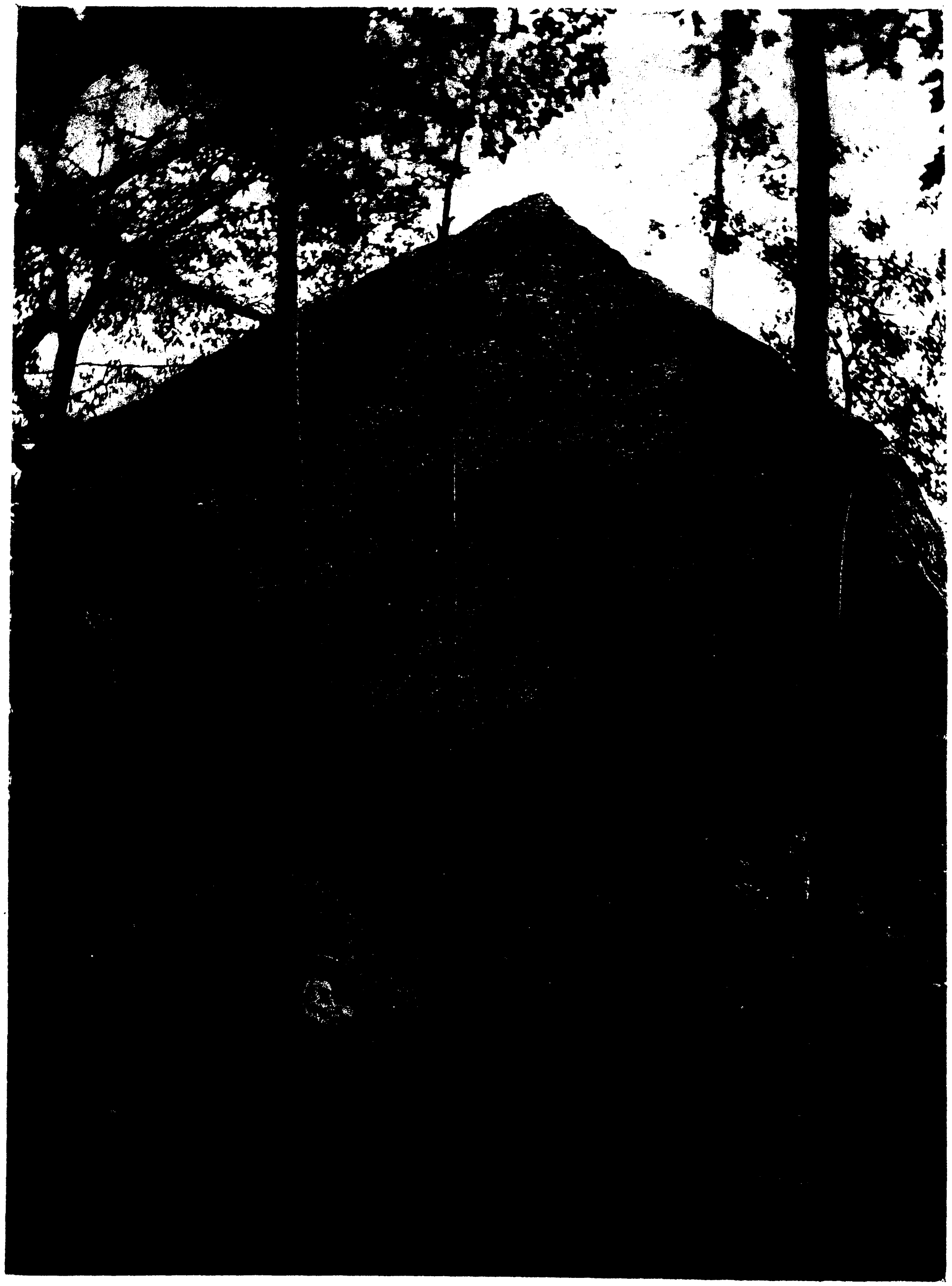
The modified drift deposits show that the ice retreated slowly, and with varying rates of progress (pp. 36, 39, 121, 122, and 149). Evidence of its reädvance has been found in only a few places, near the coast (pp. 163 and 164). The ice-sheet appears to have continued uninterruptedly through a very long period (pp. 7–9). Doubtless it resisted the influence of the warmer climate and changed conditions before which it disappeared, continuing late like the snow in spring. Its departure at the last was correspondingly rapid; and the hardier forms of vegetable and animal life were soon established near its retreating margin.

During the *recent or terrace period* the work of deposition by the streams has not been equal to that of erosion, and they have excavated deep and wide channels in the Champlain deposits (pp. 15 and 16). In this process terraces have been formed, sloping with the stream. Neither the deposition nor terracing of the modified drift requires any submergence, as by lakes or the sea. These deposits have the form which they must naturally take, in being rapidly brought into the valley by floods, and in afterwards being partly excavated by the rivers in the process of deepening their channels.

A table is added, showing the formations which have been described in this chapter, arranged in the order of their deposition, beginning with the oldest.

GLACIAL AND CHAMPLAIN DEPOSITS IN NEW HAMPSHIRE. (DRIFT, QUATERNARY, POST-PLIOCENE, PLEISTOCENE.)

	FORMATIONS, AND THEIR DISTRIBUTION.	SYNONYMS.	REMARKS.
	Lower till, p. 9, deposited during the glacial period, pp. 4–11; found throughout the state, p. 4; often accumulated within 25 miles from the coast, and rarely farther inland, in massive, oblong, rounded hills, 50 to 200 feet high, pp. 10 and 101.	Till; ground-moraine; glacial, unmodified, or unstratified drift; boulder-clay; hardpan.	Characterized, p. 9, by its glaciated stones, its dark and usually bluish color, and its compactness and hardness. Formed, pp. 5 and 9, by long continued wearing and grinding, beneath the moving ice-sheet; overlying rounded and striated ledges, pp. 4 and 5.
DEPOSITED DURING THE CHAMPLAIN PERIOD, p. 11.	*Intercalated clay and sand*, pp. 6, 17, and 18; about Winnipiseogee and Squam lakes, frequent, varying in thickness up to 30 feet, pp. 131–137; elsewhere, rare, pp. 108, 163, and 164.	The hypothesis of Mr. Jas. Croll, that an ice-sheet was accumulated and melted away several times during the glacial period, is considered in pp. 5–9.	In the Lake district, deposited where drainage was obstructed, in hollows melted under the margin of the departing ice-sheet, p. 137. Near the sea-coast, the Champlain period was interrupted by a reädvance of the ice, p. 163.
	Upper till, p. 10, found throughout the state, p. 4; thickness, usually less than 10 feet, but varying up to 20 feet or more.	By many writers not distinguished from lower till, both being included as till, glacial drift, or boulder-clay.	Characterized, p. 10, by its large angular boulders, its yellowish or reddish color, and the comparative looseness of its whole mass. Contained, with the modified drift, in the ice-sheet, and deposited when this melted.
	Kames, p. 12, found throughout the state, the extent of series varying up to 25 miles or more, and the height of ridges varying up to 250 feet. Connecticut series, pp. 43–48. Merrimack series, pp. 84–93. Ossipee series, pp. 144–149. Andover, Mass., series, pp. 167–170. Haverhill, Mass., series, p. 170.	Gravel ridges; horsebacks; moraine terraces; eskers, in Ireland; asar, in Sweden. A list of authors upon this subject is given in the foot-note on p. 174.	Deposited, pp. 13 and 14, by glacial rivers at the final melting of the ice-sheet, in channels formed upon the surface of the ice. When the bordering ice-walls and its separating ridges and masses disappeared, the gravel and sand remained in long, steep ridges, or in irregular short ridges and mounds, enclosing bowl-shaped depressions.
	Kame-like plains and broad ridges, pp. 17, 18, 155, and 156; found near the coast, about Dover, and southward to Newburyport, varying in thickness up to 100 feet, pp. 155–164, 170 and 171.	NOTE. The valley drift, kame-like plains and broad ridges, kames, and intercalated clay and sand, are all embraced under the title *modified drift*, which is defined at the top of p. 4.	Kame-like, in having been deposited, pp. 155 and 156, while the adjacent valleys and lowland were still occupied by portions of the departing ice-sheet.
	Valley drift (gravel, sand, blue and gray clay, sand), p. 15; in valleys throughout the state. A large part of these beds has been excavated by the rivers during the recent or terrace period, pp. 15, 16, 21, 27, and 82. The highest terraces are remnants of flood-plains which were annually overflowed at the end of the Champlain period, varying in height up to 200 feet above the present streams.	The blue and gray clay, pp. 94, 95, 153–155, and 158–161, are probably equivalent to the Champlain clay in Vermont, the Leda clay in Canada, and the Erie clay in the basin of the great lakes. Deltas, above the highest normal terrace, pp. 16, 29–31, 33, etc. Dunes, blown upward from the valley drift, pp. 17, 41, 73, and 147. See note in the next space above.	Brought down by glacial rivers from the melting ice-sheet, filling the valleys generally to the level of their highest terraces. This deposition and the subsequent formation of terraces required no submergence nor change in the height and slope of the land, pp. 15, 16, and 18. The height of the sea in the Champlain period was about 150 feet above its present level, as shown by marine shells, pp. 18, 165, and 166.



CHAPTER II.

GLACIAL DRIFT.

ALLUSION has been already made to the former existence of an immense thickness of ice over the whole of New Hampshire, as well as the entire northern portion of our continent. This ice-sheet is supposed to have been the natural accumulation of frozen moisture from the atmosphere, requiring thousands of years' time for its gathering together. Like the similar glacial masses upon both poles of the earth, this one must have been slowly moving towards the equator, especially near the melting edge. A formal proof of our statement is unnecessary, since the phenomena presented to us universally over the state speak for themselves; and it will be difficult for any one to read an account of the striation and embossment of the ledges, about to be described, without believing in the existence of this sheet. As the subject is one of great interest, and sound generalizations can be drawn only from observations taken in every part of the state, much attention has been devoted to the collection of facts during the whole time of our survey. Such of these as are especially important will be named: hundreds of them will not be mentioned. Many facts belong to a class, and we need therefore describe with particularity only one example of them. Should the want of time and space prevent a full discussion of the causes inducing the cold climate, the method of transportation, the chronological date of the period, and other related topics, the reader will find an excellent summary of conclusions of this nature in the preceding chapter. Treatises have been written by several geologists upon these subjects, which can be consulted by those desiring further information. It is obvious that our first duty is, to state whatever facts have been observed, and then discuss the general bearings of the subject, if an opportunity is presented. It may be premised, however, that the glacial theory of the origin of the cold and of the dispersion of the materials seems to explain all the phenomena better than the older view of the agency of icebergs.

Any complete discussion of the phenomena must relate partly to the effects produced upon the ledges by the ice-movement, and partly to a description of the materials transported, their position, shape, size, amount, etc. We will first speak of the action upon the ledges. The ledges have been broken, rounded, or embossed, planed down, smoothed, and striated. The formation of pot-holes took place after the ice began to melt.

FRACTURED LEDGES.

Since the Helderberg period, the rocks of New England had been subjected to sub-aerial decomposition, whereby they were softened and rendered friable to great depths, often as low as the water level, or as much as a hundred feet. The change was mostly chemical, consisting of the removal of the alkalies, and the disappearance of lime and magnesia, by solution, the residue being clayey. Hence the ledges were in excellent condition for removal by the ice-sheet. Enormous quantities would be easily rubbed off, and then assorted by water. Besides the decomposed rocks, the ice removed perhaps as great a mass of the solid portions, which now constitute boulders and the pebbles of the till. Still, this ice action does not represent all the erosion that has taken place in our state, as may be proved by calculations of the mass that has been removed from the ledges to fill up gaps in the strata. It has been generally estimated that this amounts to as much as the average height of the land above the sea, or 1,200 feet in New Hampshire. The condition of the surface in the Southern states, in Brazil, and in certain sheltered spots in Minnesota and Massachusetts, as described by Hunt, Hartt, White, and others, illustrates the nature of the land surface with us, before the ice acted upon it.

In the earlier New England reports, several cases of ledges fractured by the drift have been described. Clay slate is very readily broken; and the simplest cases of fracture are those noticed in that rock, as in the quarries at Guilford and Northfield, Vt. Sometimes the fractures have been produced by the expansive force of freezing. Water, penetrating the seams, freezes, and thus, by expansion, wedges apart considerable masses. These, if on a precipice, fall to the base, and accumulate in large amount. Nearly every precipice in the state exhibits more or less of this work. It will be seen, also, in the flumes about the White Mountains, and has been described in Volume II, page 158.

The frontispiece of Volume I exhibits the condition of the ledges in a certain stage of decomposition, between the upper limit of trees and the snow line. Doubtless many square miles of surface were thus covered by angular blocks before the ice-movement commenced.

The most striking evidence of the action of ice breaking ledges is where the stone has been fractured by a lateral thrust. These are commonly seen about large quarries. A single example will suffice for many that have been observed. Fig. 49 is a sketch of this phenomenon at the Amoskeag granite quarry in Manchester. It is upon the north-west slope of a hill, in a position where it could be struck by the ice descending the Merrimack valley. The surface is smoothed and striated. For eight or ten feet in depth the granite is broken into irregular pieces, so that it cannot be used for underpinning. Beneath these pieces, the stone is sound at least to the depth of thirty feet, or as far as the excavation has proceeded. One can readily see the line between the broken and sound stone upon the east side of the quarry. That the fracture was occasioned by the ice-movement is proved by the fact of the smoothness of the surface fragments. The pieces can be taken out and matched together again, just like a pavement. Had they been fragments prior to the ice-action, they would have been moved away by it. The same phenomenon occurs, though less noticeably, at Bodwell's quarry, close by. If the ice had reäppeared in the Merrimack valley, these broken fragments would have been removed, and a new smoothed and striated surface would have been planed upon the solid granite.

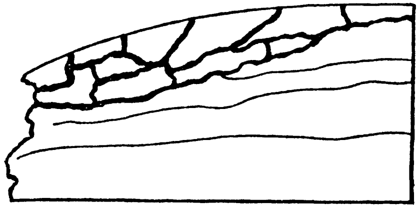


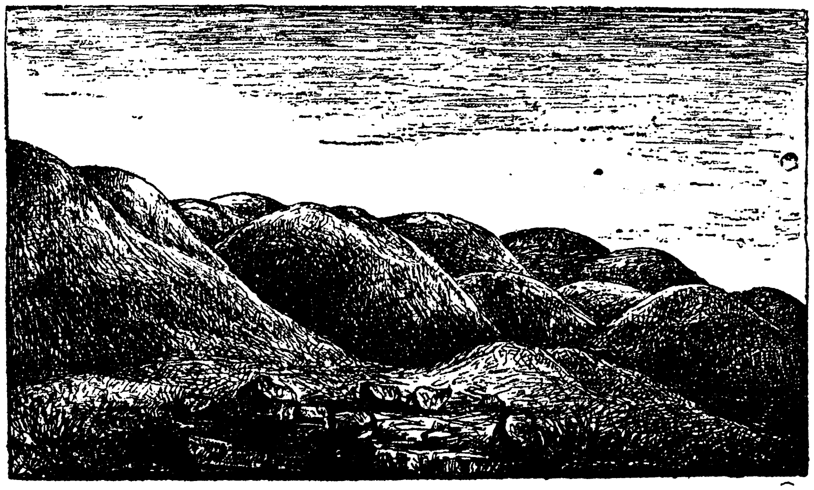
FIG. 49.

There is reason to believe that examples similar to the above exist by the hundred. They are not usually visible, except where excavations have been made.

PLANISHING AND EMBOSSMENT.

Should the earth be entirely removed from the ledges, the majority of them, save where subsequent erosion has obliterated the marks, would show upon their exposed sides a planing down and rounding. These ledges are not planed down flat, like a floor, but are rounded, retaining essentially their original forms. It is a common sight, when travelling along the deeper valleys, to observe, above the line of the modified drift, numerous rounded, dome-shaped ledges. A close scrutiny will disclose the fact that these have been worn the most upon the northern side, while the southern escarpment may be rough and uneven. Hence it is obvious from which direction the force proceeded which planed down the ledges. The sides most worn are those which have been struck. We often speak of the struck or *stoss* and the *lee* sides of these rounded ledges.

The embossed ledges are often grouped in considerable numbers, looking as if there were an assemblage of haystacks closely crowded together. Precisely similar phenonena occur in the glaciated region of the Alps, where De Saussure applied to them the name of *roches moutonnes*. An example of them, as seen in New Hampshire, is given in



[FIG. 50.—EMBOSSED ROCKS ON MT. MONADNOCK.

Fig. 50. This represents an area of about five rods square on the southwest side of Mt. Monadnock. Here they occur near the summit of the mountain, not along the sides of a valley.

There are many examples of embossment in the state as good as these. I have noted a few of them: The top of Mt. Kearsarge; about the Lake of the Clouds, between Mts. Washington and Monroe, though the action of the frost is injuring their perfection; along the Pemigewasset valley in Woodstock; Baker's River valley, in the west part of Plymouth and the east part of Rumney,—also higher up, less perfectly; along the Northern Railroad, between Orange summit and Grafton Centre; Sanbornton, west of Cawley's pond. The Huronian and Cambrian slates of the Connecticut valley abound in fine examples of these rock domes. Others are specified in the column of remarks about striæ, further along. The narrow belt of rock in which the principal mica quarries are located, between Groton and Keene, is noticeable for the very fine embossment of the ledges all over its course. Granitic and calcareous rocks decompose readily; but the general form of the embossment will remain after the markings have been obliterated, so that a practical eye will recognize the fact of their glaciation.

STRIATION.

By far the most important effect of the ice-movement is the striation. All these domes and the worn sides of ledges exhibit lines more or less distinct, or passing into grooves which have been produced by hard rock fragments frozen into the bottom of the ice-sheet. As the mass moved along, these fragments acted as chisels or gouges, deeply scratching the ledges. It is obvious that the grooving instrument must have been harder than the rock affected; hence pieces of soft rocks, like limestone, would not leave any mark of their passage. These markings are often obliterated by disintegration, and it is difficult to find their direction. Several expedients may be resorted to: First, search for veins or projections of tough materials, upon which faint lines may possibly be found. These harder substances show the action, because they have successfully resisted disintegration. Again: it may be necessary to wet these projections, or the whole surface of a smoothed rock, in order to discover the direction of the striæ. Sometimes deep grooves may be found, which will indicate the course as well as scratches.

These markings vary from the finest scratches visible to deep furrows. They may be straight or curved, the latter where the abrading chip turned to one side, and was speedily crushed. Again: pieces of the rock may be chipped off, as if the chiselling fragment was not held down firmly to the ledge, but had a jarring motion. Then there are the lunoid furrows. Vose describes them upon the Green hills in Conway. Some seen on their northern slope have axes running about S. 40°–48° E., and are from one to four inches in diameter. A section of one is given in Fig. 51. It appears that the steep side, A, is always on the up-hill end of the furrow. Four others were noted at the south end of these same hills, upon a horizontal surface near the summit. They are figured in Fig. 52, are 11 inches long, 7 wide, and 4 deep, their direction being that of the dotted line, N. W. and S. E. These axes indicate the course of the ice-movement.

LUNOID FURROWS.

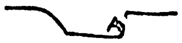


FIG. 51.

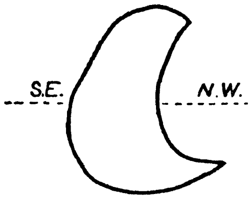


FIG. 52.

The origin of the lunoid furrow is given as follows by Dr. A. S. Packard, Jr., who observed several of them on a hill near Goodrich falls in Bartlett, with the course S. 17° W., also on Mt. Baldface:[*] "It is known that the glacier is in constant motion, advancing a few inches in summer, and then contracting in winter. Now imagine a stone frozen into the ice, and thus acting as a gouge. Pushed onward, and then withdrawn by the powerful hand of the ice-king, it soon wears this peculiar shaped hole, then turns out of the rut, and catches again in some inequality of the rock, and makes another lunoid furrow, or, perhaps, a series of four or five, often very regular in form, though the distance between them may vary."

The striæ in New Hampshire vary considerably in their direction. Before discussing the reasons for this variation, it will be proper to present a list of all the observations of their occurrence that have been recorded. They are all my own, except the few that are otherwise noted. I have carefully reduced the compass to true courses. I hope to present in the atlas a map showing these marks laid down with great care in connection with the relief features of the ground. A very few observations may be added for the adjoining territory, or what is included in our general map.

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[*] *American Naturalist*, vol. i, p. 265.

COURSES OF STRIÆ IN NEW HAMPSHIRE.

LOCALITY.	ROCK.	TRUE COURSE.	REMARKS.
Pittsburg,—mouth of Indian stream	Slate	S. 58° E.	
1 mile S. E. from Back lake	Huronian	S. 58° E.	Numerous embossed ledges.
Outlet of Connecticut lake	“	S. 64° E.	
Saw-mill near do	“	S. 44° E.	
D. Merrill's	Whetstone grit	S. 44°–50° E.	Very distinct. J. H. Huntington.
Col. Huggins's	Diorite	S. 43° E.	“ “
Mt. Carmel	“	S. 25° E.	Grooves. “ “
Stewartstown,—mouth of Bishop's br.	Slate	S. 24° E.	
J. Brainerd's	“	S. 17° E.	Local glacier. J. H. Huntington.
South hill	Calc. mica schist.	S. 34° and S. 52° E.	Very distinct. “ “
Clarksville,—M. Perry's	“	S. 34° E.	
S. W. corner, top of hill	“	S. 34° E.	
J. Gethercole's, “	“	S. 44° E.	
J. Keyser's	“	S. 44° E.	J. H. Huntington.
Colebrook,—J. S. Chase's	“	S. 38° E.	
Young's—east part	Huronian	S. 35° E.	
Dixville,—top of Dixville mountain	Mica schist	S. 54° E.	
Dalton,—near Sumner house	Huronian	S. 8° E.	
Copper mine	Clay slate	S. 2° W–S. 3° E.	
R. Miller's	“	S. 3° E.	
Monroe,—A. Mason's	Lisbon group	S. 2° E.	
East of Albee's house	Lyman group	S. 2° E.	Striæ abundant in North Monroe.
Top of hill, do	“	S. 2° E.	
G. Lang's	Lisbon group	S. 2. E.	Finely embossed ledges.
Top of Gardner's mountain	“	S. 12° E.	
Way's copper mine	“	S. 8° W.	
Top of Gardner's mountain	“	S. 12° E.	
Lyman,—No. 1 shaft, Paddock mine.	Lyman group	S. 6° W.	Deep grooves.
Land of Martin and Swett	Conglomerate	S. 2° E.	
Near do		“	
Hill back of Steery's house	Slate	“	
Dr. Brown's barn	“	“	
Near Bedell's house	“	S. 3° W.	
Near Bath line south from Dow's.	Conglomerate	S. 12° E.	Running up hill.
Hill opposite J. Williams's	Slate	S. 2° E.	
North of S. B. Presby's		S. 35° E.	Down small valley. Different from the usual direction in the neighborhood.
North of Young's pond		S. 8° W.	
Moulton hill	Lyman group	S. 8° W.	
Dan. Miner's	“	S. 2° E.	Diagonally up hill.
S. W. part of Parker & Young's.	“	S. 3° W.	
Stakes 17 P. to R. (vol. ii, p. 296).	Clay slate	S. 2° E.	Numerous and fine.
Near R-6	“	“	
U-14	Slate	S. 8° W.	
J-6	“	S. 2° E.	On vertical wall.
C-17	“	S. 12° E.	Up hill, athwart valley of Smith brook.
B and A-17	“	S. 2° E.	Top of hill.
H-21	“	“	
Littleton,—Mann's hill	Conway group	S. 12° E. and S. 7° E.	
A. Annis's	“	S. 2° E.	
R. Moore's, south of Cow brook.	Huronian	S. 4° W.	
Ridge between Cow and Parker brooks	“	S. 7° E.	
Near Dalton	“	S. 2° E.	
Farr hill, near fossils	Clay slate	S. 8° W.	
Milliken's saw-mill	Huronian	S. 2° E.	These striæ cross the Conn. valley.
East of G. Wheeler's—hill	“	S. 3° W.	
A. P. Hubbard's	Clay slate	S. 8° W.	
West side Fitch hill	“	S. 27° E.	
Haverhill,—Woodsville	Huronian	S. 2° E.	
Soapstone bed		S. 13° W.	
¼ mile N. W. from limestone	Gneiss	S. 21° E.	
Newbury, Vt.,—village	Huronian	S. 2° E. and S. 22° E.	The second set only a few stragglers.
Dam—Wells river. G. Leslie	“	S. 8° W.	
George Swasey's	“	S. 7° E.	
Errol,—S. E. part	“	S. 73° E.	Numerous. G. W. Hawes.
Carroll,—hill back of Twin mount'n	Bm. gneiss	S. 33° E.	
Lancaster,—near P. McLary's		S. 23° E.	
Ridge west of Mt. Pleasant	Quartz rock	S. 10° E.	Very distinct. J. H. Huntington.
Milan,—west part	Huronian	S. 42° E.	Magnificent.
Hodgdon hill	“	S. 42° E.	J. H. Huntington.
Lisbon,—near Mink pond	Coös schists	S. 18° W.	
Near poor-house (further east)	Gneiss	S. 18° W.	
Sugar hill, near Quimby's	Coös schists	S. 12° E.	

Courses of Striæ—Continued.

LOCALITY.	ROCK.	TRUE COURSE.	REMARKS.
Hill-top east of Bronson hill	Gneiss	S. 5° W.	
Hill south of Atwood mine	Huronian	S. 8° W.	
Between Streeter pond and N. Lisbon	Clay slate	S. 8° W.	
Jesseman's	Limestone	S. 2° E. and S. 28° E.	Two different localities, the same course.
Bethlehem,—west part, top of hill	Gneiss	S. 3° W.	
South slope of Mt. Agassiz	"	S. 3° W.	N. W. slope Agassiz range abundantly striated similar to this.
C. Kenney's and Quimby's	Gneiss	S. 28° E.	
Line of Bm., near iron works	Gneiss	S. 3° W.	Struck side very evident.
Mt. Agassiz—top	"	S. 8° W.	
¼ way up from toll-house	"	S. 12° E.	Up hill.
C. Huntoon's	"	S. 28° W.	
L. Blondin's	"	S. 4° W.	
Landaff,—high hill above J. Clough's.	Quartzite	S. 3° W.	
Bath,—I. Cooley's	Lyman group	"	
Top of Gardner mountain	Huronian	S. 12° E.	Very fine.
West side	"	S. 3° W.	
Franconia,—R. Wallace's	Gneiss	S. 8° W.	
White Mountains,—ridge N. E. of Mt. Madison	Montalban		Rock struck on north-west side.
Presidential Range.			
Mt. Adams, west side—5500 feet high	"	S. 58° E.	According to W. G. Nowell.
Mt. Adams, smaller S. W. peak, south part	"	"	
Near gap between Adams and Jefferson	"	S. 33° E.	
Top of Mt. Washington	"	S. 43° E.	Smoothing distinct; striæ obscure.
200 ft. above Lake of the Clouds.	"	S. 30° E.	
Lake of the Clouds	"	S. 22° E. and S. 52° E.	Intersecting.
Between Pleasant and Franklin	"	S. 30° E.	
Between Pleasant and Clinton	"	"	
Near top of Clinton, north side	"	S. 47°–52° E.	Very distinct.
Clinton, south peak	"	S. 50° E.	
South end of Mt. Webster	"	S. 37° E.	
Top of Mt. Webster	"	S. 30° E.	Rock face; 200 by 40 feet exposed. N. E. clearly the side exposed.
Mt. Washington carriage-r'd,—lower end	Coös	S. 22° W.	Well defined example of the same on vertical walls.
2 miles up	"	"	Upon an easterly dipping slope of 30°.
2½ miles up	"	S. 8° W.	Intersecting; wall surface freshly uncovered.
5 miles up	"	S. 2° E. and	
Glen house	Montalban	S. 15° W.	
Do. ½ mile south	"	S. 3° W.	
Head of Tuckerman's ravine	"	S. 55° E.	Modern striæ made by falling stones.
Gorham,—about village	"	About S. E.	Stoss side points up valley.
Shelburne,—hill 150 ft. above R. R.	"	S.88°–N.87°E.	
Extreme north point of curve	"	S. 63° E.	
Clement's brook	"	S. 73° E.	
Near Maine line	"	S. 58° E.	
White Mountains			
Mt. Lafayette, above Eagle lakes.	Lake gneiss	S. 8° W.	Many large boulders above lakes.
Bald mountain	Porph. gneiss	S. 2° E.	Large boulder of B'm gneiss on top.
Mt. Field, side towards Mt. Willard	Granite	S. 37° E.	
Small local ones across preceding		N. 73° E.	
Mt. Field—top	Slate	S. 50° E.	
Mt. Willey—top	"	S. 42° E.	
Hart's mountain	Montalban	S. 52° E.	
Mt. Tom—N. E. side	Slate	S. 57° E.	Wall.
" S. side	"	"	Down hill.
Mt. Pequawket—part way up	Granite	S. 45° E.	C. T. Jackson.
"	Slate	S. 40° E. and S. 60° W.	Intersecting. G. L. Vose.
" ⅔ way from top to saddle between Pequawket and Bartlett mountain, 2500 feet high		S. 42° E.	
The "Notch,"—south side Mt. Willard and near railroad		S. 2° E.	Down valley.
On railroad south side of Willey brook	Slate	Southerly.	Down valley; seen both sides of track.
Top of Mt. Willard	"	S. 23° E.	
West side Sandwich notch near top	Gneiss	S. 70° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Saco valley, below Bemis's	Gneiss		Wall; down valley; recently excavated by railroad.
Duck Pond stream	"	S. 18° E.	Wall inclined 45° W.
Ossipee mountain—Mt. Whittier—top	Granite	S. 47° E.	
Same—east side	"	S. 32°–S. 37° E.	Intersecting.
Bartlett,—N. E. part	Granite	S. 53° E.	G. L. Vose, in gap between Goodrich and "Sligo."
Hill adjoining Goodrich falls	"	S. 17° W.	A. S. Packard, Jr.
Jackson,—last house next Carter notch	Montalban	"	A few cross valley, S. 33° and S. 83° E., curving around a ledge.
Thorn mountain—top	"	S. 38° E.	A. S. Packard, Jr.
Mt. Baldface—top	Granite	S. 23°–28° E.	" "
Thorn mountain, depression on north side	Slates	S. 55° E.	G. L. Vose.
Cook's	Mica schist		Down valley.
Benton,—Mt. Moosilauke—top	"	S. 22° E.	
20 rods east of summit	"	S. 27°–32° E.	
Mt. Moosilauke, ¾ way up	"	S. 52° E.	Local or slide. (?)
Warren,—back of Merrill's, lower end of turnpike	Gneiss	S. 57° E.	Down tributary of Baker's river—local.
Berry brook	"	S. 37° E.	Down valley.
"	"	S. 22° E.	Grooves down the valley.
1 mile south of Kelley pond	"	S. 52° E.	Down valley; rather obscure.
North of I. H. Kelley's	"	S. 12° E.	
Wentworth,—near village	"	S. 22° E.	
Rumney,—West Rumney, north side of river	Mica schist	S. 37° E.	Wall 5 feet high.
Hill south-west of village	Mica schist	S. 35° E.	Very distinct. J. H. Huntington.
Lower down	"	S. 37° S. 42° S. 57° E.	Corresponding to bend of valley.
Baker's River valley	"	S. 52° E.	Wall.
1 mile east of village	Andalusite schist.	S. 62° E.	
Up hill towards Groton	Montalban	S. 52° E.	
A. Kelley's	"	"	On wall 40 feet high; hill opposite high and precipitous.
E. Blodgett's	"	S. 57° E.	
Plymouth,—west line	"	S. 42° E. and S. 57° E.	
Village—W. edge R. Easter	Gneiss	S. 62° E.	
South side Plymouth mountain, ½ mile east of Hebron line		"	Down hill across valley.
Line of Hebron and Plymouth	Montalban	S. 22° E.	
Top of Wolf hill	Granite	S. 52° E.	
½ mile south of village	Ferrug. gneiss	S. 42° E.	Partly on wall.
Hebron,—summit near line of Plymouth	Montalban	S. 29° E.	
Hill east of Newfound lake	"	S. 22° E.	
North end " "	"	S. 37° E.	Acres of embossed ledges at north base of Kimball hill.
West part	"	S. 33° E.	
Groton,—Down valley, S. Groton	Porph. gneiss	S. 42° E.	
Just in town, 450 feet above railroad at Rumney	Montalban	S. 52° E.	
At M. V. B. Kinne's, height of land	"	S. 32° E.	
West part		S. 22° E.	J. H. Huntington.
Summit between Groton and Orange	Gneiss	S. 32° E. S. 32° E.	
I. D. Southwick's	"	S. 40° E.	J. H. Huntington.
Pemigewasset Valley. Mt. Pemigewasset, Lincoln	Granite	S. 12° E.	On vertical wall, with valley.
North Woodstock	Porph. gneiss	S. 22° E.	Magnificent embossment of mountains.
Woodstock post-office	Gneiss	S. 2° E.	
Lower	"	S. 34° E.	
South part		S. 30° E.	
Thornton		S. 22° E.	
"		S. 27° E.	
"		S. 22° E.	
top of mountain south of Russell pond		S. 23° E.	Faces Pemigewasset river.
S. W. from H. Fifield's		S. 32° E.	
Near M. Sargent's		S. 22° E.	
" H. K. Hill	Porph. gneiss	S. 26° E.	
Towards Sandwich notch, three fourths mile from Mad river	Montalban	S. 70° E.	W. Upham.
1 mile S.E. from West Thornton		S. 15° E.	
West Campton	Porph. gneiss	S. 22° E.	
Campton north line, in river	"	S. 27° E.	
Holderness,—Mt. Prospect—summit.	"	S. 37° E.	
" W. side.	"	S. 35° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Shepard's hill	Porph. gneiss	S. 62° E.	
Squam mountain—top	"	"	
Ashland,—near depot	"	S. 42° E.	
Village turn to lake, hill road	Ferrug. schist	S. 32° E.	
Waterville slide	Labradorite	N. 32° W.	Perhaps made in 1869.
Sandwich,—W. of vil., J. Goodwin's.	Gneiss	N. 78° E.	
M. Bean's	"	N. 83° E.	
West line	"	S. 82° E.	Down a valley depression.
N. E. corner of Squam lake	"	N. 85° E.	
North foot of Red hill	Sienite	N. 80° E.	
S. Dinsmore's	Gneiss	N. 78° & 83° E.	
At notch	"	S. 60° E.	Two places. W. Upham.
¼ mile north of Dinsmore pond.	"	East.	W. Upham.
Moultonborough,—near S. E. town line	"	S. 55° E.	
H. Smith's	"	S. 57° E.	
Red hill, near summit	"	S. 62° E.	
D. Vickery's	"	S. 72° E.	Obscure.
Center Harbor,—west of landing—Mrs. Sutton's	Lake gneiss	S. 72° E.	
Middle of township	"	S. 42° E.	
Common all through township	"	"	
Near M. Wade's, promontory of Squam lake	"	S. 57° E.	
West of Bear pond	"	S. 42° E.	
Tuftonborough,—"Corner"	Ferrug. schist	N. 68° E.	
Near Melvin hill	Gneiss	S. 25° E.	
Below Melvin village	"	S. 27° E.	Two last on hills west of Lower Beech pond.
2 miles south of "Corner"	"	N. 80° E.	
½ mile south of last	"	E.	
Wolfeborough,—west side of Trask hill (G. M. Garland's)	Lake gneiss	S. 85° E.	Rather obscure.
Top of Trask hill	"	S. 50° E.	
1 mile N. E. of Wolfeborough Centre (E. of L. Shotridge's)	"	S. 40° E. & E.	
Porcupine ledge	Quartz	S. 60° E.	
N. W. Tibbetts's	"	"	
R. H. Piper's, north side of Mt. Delight	"	S. 65° E. S. 50° E.	
Tumble-down Dick	"	S. 65° E.	
Brookfield,—north of Tumble-down Dick	"	S. 65° E.	
North corner of town	"	S. 55° E.	
2 miles south of last	"	S. 70° E.	
J. Perkins's	Mica schist	S. 52° E.	
D. F. Stoddard's	Gneiss	S. 72° E.	
Top of Moose mountain	Granite	S. 32° E.	
200 feet lower	"	S. 42° E.	
Wakefield,—L. C. Perry's	Gneiss	S. 52° E.	
South of Sanborn's, junction	"	S. 57° E.	
Top of hill near J. Copp's	"	S. 37° E.	
North of S. Cook's—high land	"	S. 57° E.	
Three Tibbetts' houses	"	S. 72° E.	
		S. 52° E.	
Near East pond	Mica schist	S. 42° E.	
Ossipee,—East of Leighton's corner.	"	S. 22° E.	
Hill south of I. L. Sanders's	"	S. 42° E.	
Freedom,—Small hill west of village.	Montalban		Towards village of Freedom.
E. Woods's	"	S. 22° E.	
Madison,—J. L. Frost's, near village.	"	S. 2°. E. x S. 22° E.	
R. Brown's, north of village	"	S. 12° W.	
1 mile west of Silver lake	"	S. 7° W.	
Gline mountain (road over)	"	S.	Excellent; broad floors.
Eaton,—hill, north-east corner	"	S. 30 E.	
Tamworth,—Chatham hill, near top.	"	S. 42° E.	
South of Chocorua house	"	S. 18° W.	G. L. Vose.
Top first rise towards Mt. Chocorua	"	S. 27° E.	"
Top of second do	"	S. 7° E.	
Side of Mt. Chocorua	"	S. 42° E.	C. T. Jackson.
Meredith Neck,—Rollins hill	Mica schist	"	Summit is one large embossment 30 feet long, 10 feet high, and 10 feet wide.
Advent church on Neck	Gneiss	"	
2 ms. N. of M. village—summit	"	"	5° less easterly 50 ft. below the summit.
East of Long pond	"	S. 37° E.	
East line, next Center Harbor	"	S. 40° E.	
Centre—hill to the south	"	S. 27° E.	
Village	"	S. 42° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
New Hampton,—N. W. part, clay deposit	Andalusite schist.	S. 37° E.	
Harper's hill	Porph. gneiss	S. 52° E.	Plain, and running up hill.
Centre	“	S. 42° E.	Abundant; embossed ledges numerous.
Edge, next Meredith	“	S. 52° E.	
Beyond		S. 37° E.	Course with valley.
West edge of N. H. village	Gneiss	S. 57° E.	
North side Burleigh mountain	Montalban	S. 32° E.	Down valley; many emb. ledges here.
North side White Oak hill	“	S. 37° E.	“ “ “
Laconia,—	“	S. 27° E.	
Dr. J. L. Perley's	“	about S. 27° E.	
Mrs. M. Gale's, top of hill	“	S. 14° E.	
Gilford,—near Weirs	Porph. gneiss	S. 35° E.	
H. Hunt's	Ferrug. schist	S. 37° E.	
E. of Lake Village—M. C. Dexter's	“	S. 42° E.	
Hill south of L. Gove's	Mica schist	S. 35° E.	
Gilmanton line	“	S. 32° E.	
Top of Mt. Gunstock	Trap dyke	S. 62° E.	A single scratch.
Marks's island, Winn. lake	Gneiss	S. 42° E.	
Sanbornton,—Back of Sanbort'n Sq., 1 mile to the north-west	Mica schist	S. 22° E.	
North part—T. B. French's	“	S. 24° E.	
Ridge in north part	“	S. 42° E.	
Further south	“	S. 32° E.	
“Gulf”	“	S. 22° E.	Two places. W. Upham.
Road west of Hopkinson hill	“	S. 15° E.	“
1 mile north “ “	“	S. 35° E.	
Belmont,—B. Chase's	“	S. 32° E.	
Line of B. & G	“	“	
K. Hall's	“	S. 42° E.	
Gilmanton,—hotel	“	“	
South-east from hotel	“	S. 52° E.	
C. Gilman's	“	S. 42° E.	
Lower Gilmanton village	“	“	
I. P. Hill's	“	S. 52° E.	
North-west part of town	“	S. 32° E.	Grooves.
C. A. Hackett's	“	S. 36° E.	
East part, top of hill	“	S. 47° E.	
Tannery, south edge of town	“	S. 42° E.	
North-east part	“	“	
Hall's hill, south-east part	Gneiss	S. 52° E.	
2 miles east of Peaked hill		S. 45° E.	W. Upham.
Tilton,—near village		S. 14° E.	
Alton,—east line	Montalban	S. 42° E.	
D. & J. Varney's	“	S. 37° E.	
J. Morrison's, west of lake	“	S. 42° E.	Also a few straggling to S.; all up hill.
N. S. Straw's	Gneiss	S. 57° E.	
W. of L. S. Nute's, top of ridge.	“	S. 52° E.	
H. Hunt's, north-east part	“	S. 17° E.	
New Durham,—B. F. Sawyer's and J. B. Burnham's	Montalban	S. 42° E.	
West part	“	“	
Brook in east part	“	S. 52° E.	
G. D. Savage's	“	“	
W. H. Tush's	“	“	Unusually fine.
“Ridge”	“	S. 67° E.	
Church on ridge and ¼ m. west.	“	S. E.	W. Upham.
Barnstead,—S. W. Young's	Gneiss	S. 52° E.	
Clark's corner	“	“	
Strafford,—Corner	Mica schist	S. 72° E.	Obscure.
S. Young's	“	S. 52° E.	
Ridge north	“	S. 57° E.	
Top of ridge, north-west part	“	S. 42° E.	
South of D. Marsh's	“	S. 32° E.	
North end of Bow lake	Gneiss	S. 58° W.	
1 mile north	“	S. 31° W.	
2 or 3 miles north-east, in Paul Tasker's pasture	Quartz	S. 35° E.	
North-west corner	Mica schist	“	
East of Isinglass river	“	S. 62° E.	
G. W. Foss's	“	“	
A. W. F	“	S. 35° E.	
½ mile S. W. from south corner.	“	S. 40° E.	Two places. W. Upham.
1 “ “ “	“	“	“
Farmington,—west side Hussey mt.	“	S. 52° E.	
O. K. Otis's	“	“	
South Farmington	“	S. 42° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Milton,—top of Teneriffe mountain	Mica schist	S. 42° E.	Grooves seen 50 feet long.
N. H. Roberts's	"	"	
Rochester,—north-west from village.	Andalusite schist.		Abundant; not measured.
2 miles south	"	S. 24° E.	
J. F. Young's	Mica schist	S. 27° E.	
Barrington,—Wheeler Foss's	"	S. 42° E.	
Rollinsford,—E. S. Clement's	"	S. 12° E.	
Durham,—W. P. Sherburne's	"	S. 37° E.	
West of J. W. E. Thompson's	"	S. 52° E.	
North-west part	Sienite	S. 57° E.	
Lee,—school-house No. 1	Mica schist	S. 42° E.	
Northwood,—centre	Montalban	S. 37° E.	
Top of Saddleback mountain	"	S. 32° E.	Grooves.
Pittsfield,—Catamount hill—top	Mica schist	S. 42° E.	
Chichester,—1 mile south-east from Kelley's corner		S. 20° E.	W. Upham.
Deerfield,—hill-top near J. Chase's	Merrim'ck schist.	S. 40° E.	
Middle part	Gneiss	"	
North side of Pawtuckaway	"	S. 72° E.	
Epsom,—east line	"	S. 36° E.	
Canterbury,—south edge	Montalban	S. 16° E.	
Further north	"	S. 20° E.	
Soapstone quarry	Soapstone	S. 26° E.	
1 mile N. E. from North Concord station		S. 15° E.	W. Upham.
⅓ m. S. from Canterbury centre.		S. 25° E.	"
¼ m. N. of Crane Neck pond		S. 40° E.	"
¼ m. N. W. from Shaker Village.		S. 30° E.	"
Franklin,—west part of village	Montalban	S. 17° E.	
H. George's	"	S. 32° E.	
North of village	"	S. 27° E.	
Near Hill	"	S. 42° E.	Bends with Merrimack valley.
Near north-east edge	"	S. 22° E.	Down a valley.
South-west corner	"	S. 42° E.	
1 mile north-east from falls	"	S. 15° E.	W. Upham.
Hill,—near church	"	S. 22° E.	
Andover,—near centre	"	S. 62° E.	
Potter Place	"	S. 67° E.	
Top of hill south of centre village.	"	S. 38° E.	Also south-east on a wall, and down hill to the south.
Near J. Farnum's—high hill	"	S. 57° E.	
Salisbury,—S. part, top Bean's hill	Porph. gneiss	S. 22° E.	
South village	Montalban	S. 12° E.	
J. S. Morrill's	"	S. 15° E.	
Boscawen,—near village	"	S. 27° E.	
Back of Fisherville	"	S. 17° E.	
Kearsarge mountain,—top	Andalusite schist.	S. 46°–51° E.	Remarkably fine.
Top of clearing, north-west side.	"	S. 36° E.	All the way up the mountain.
Above Winslow house	"	"	
At " "	"	"	
¼ mile north of Winslow house	"	S. 41° E.	
North side	"	S. 76° E.	
	"	S. 46° E.	
South side of "White house"	"	S. 71° E.	
Toll-gate of turnpike	"	S. 51° E.	
West side, in Sutton	"	S. 11° E.	
Ragged mountain, Andover, top	"	S. 23° E.	
	"	S. 36° E.	
	"	"	
		S. 56° E.	
Monadnock mountain.			
East edge of Jaffrey	Mica schist	S. 11° E.	
Jaffrey	"	"	
A. Baker's S. W. corner of Jaffrey	Andalusite gro'p.	S. 31° E.	
Monadnock house	"	S. 46° E.	Also S. 75° E., or perhaps N. 75° W.; local.
East and south-east sides of top	"	S. 21° E.	
South-east side, local sliding	"	S. 56° E.	
Top	"	S. 21° E.	
South-west of top	"	S. 51° E.	
Somewhat lower down	"	S. 61° E.	
Still lower	"	S. 51° E.	Slope to south.
New London,—near south line	Gneiss	S. 31° E.	
George's mills	"	S. 46° E.	
Sutton,—south part	Porph. gneiss	S. 59° W. and S. 11° E.	
Mills	"	S. 11° E.	
Nelson hill	"	S. 28° E.	
Newbury,—E. Nelson's	"	S. 11° E.	

Courses of Striæ—Continued.

LOCALITY.	ROCK.	TRUE COURSE.	REMARKS.
Bradford,—Baptist church	Porph. gneiss	S. 25° E.	
North-east corner	Gneiss	“	W. Upham.
“Joppa”	“	S. 25° and S. 20° E.	C. T. Jackson.
Warner,—south side of Mink hills	Porph. gneiss	S. 26° E.	
South of Levi Bartlett's	Gneiss	S. 21° E.	
Concord,—south foot of Horse hill	Montalban	S. 9° E.	
Mast Yard	“	S. 11° E.	
South of Rattlesnake hill	Granite	S. 21° E.	
Phenix quarry	“	S. 11° E.	
½ mile north of Snow's pond		S. 17° E.	W. Upham.
Loudon,—1 mile N. E. from village		S. 15° E.	“
½ mile south-east from “Ridge”		S. 25° E.	“
North-east corner		S. 40° E.	“
Hopkinton,—east part	Ferrug. schist	S. 10° E.	
Henniker,—village	Gneiss	S. 11° E.	
Dunbarton,—Wedge—hill-top	Lake gneiss	S. 21° E.	
School-house east of Kimball pond and further east—high	Montalban	“	
S. H. Woodbury's	“	S. 10° E.	W. Upham.
Bow,—school-house, south corner	“	S. 38° E.	
S. H. & J. H. Bartlett's	“	S. 21° E.	
L. White's	“	S. 38° E.	A downward slope.
Hooksett,—near village	Gneiss	S. 26° E.	
Back from village	“	S. 18° E.	
Campbell's hill	Quartzite	S. 21° E.	
1½ miles west Merrimack S. pt.	Gneiss	“	
Manchester line, E. side of river	“	S. 16° E.	
Rowe's old station	“	S. 41° E.	
Manchester,—fair ground	“	S. 26° E.	
South-east part	“	S. 15° E.	
Methodist church, Hallsville	“	S. 16° E.	
Amoskeag quarry	Granite	“	
“ “ local	Mica schist	N. 40° W.	
Same neighborhood	Gneiss	S. 41° E.	
Bridge, Hanover street crossing	“	S. 26° E.	
Outlet of Massabesic lake	“	S. 21° E.	
Candia,—top of hill, west part, J. Emerson's	“	S. 31° E.	
Store, H. M. Eaton's	“	S. 26° E.	
East line	“	S. 36° E.	
Patten's hill	“	S. 21° E.	
Raymond,—2 miles north of railroad (hill)	Mica schist	S. 28° E.	
Abbott & Smith's, further north	“	S. 41° E.	Exposed 40 feet long.
Flint hill	Quartzite	S. 36° E.	
North of, at B. Dearborn's	Mica schist	S. 31° E.	
South part	“	S. 51° E.	
North of village	“	S. 31° E.	
Hill west of Flint	“	S. 41° E.	
W. Titcomb's	“	S. 26° E.	
Epping,—D. Kennard's	“	S. 28° E.	
North line	“	S. 21° E.	
A. Randlett's	“	S. 31° E.	
East of H. Bly's	“	S. 31° E.	
Nottingham	“	S. 31° E.	
West side of square, same hill	“	S. 56° E.	
¼ mile north-west from square	“	S. 20° E.	W. Upham.
¼ mile south-east from square	“	S. 20° E.	“
East of hotel	“	S. 31° x 41° x 46° E.	Intersecting.
Fremont,—B. Poor's	Gneiss	S. 31° E.	
I. Sanborn's	“	S. 36° E.	
Exeter,—south-west of village brook	Merrima'k schist	S. 52° E.	This is usually covered by water.
E. C. Sanborn's	Sienite	S. 24° E.	
Stratham,—near B. Howe's	Merrima'k schist	S. 27° x 47° E.	Intersecting.
Greenland,—north of church	“	S. 27° E.	
Portsmouth,—powder magazine	“	S. 12° E.	
¼ mile west of Newcastle bridge (south end of town)	“	S. 37° E.	
School-house, N. part of houses (¼ mile from depot)	“	S. 32° E.	
Rye,—Sagamore house	“	S. 52° E.	At ocean level.
South of Sagamore river	“	S. 35° E.	
Hampton,—west part	“	S. 42° E.	
Seabrook,—north part of village	“	S. 52° E.	Same seen obscurely near post-office.
Newton,—N. Gould's	“	S. 32° E.	
Atkinson,—D. Noyes's	“	S. 42° E.	
South Kingston,—D. Collins's	Granite	S. 22° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Danville,—Wm. Bagley's	Merrima'k schist.	S. 32° E.	
Hampstead,—J. E. Emerson's	"	S. 47° E.	
Salem,—village	Gneiss	S. 22° E.	
Granite quarry	"	S. 22° x 72° E.	Intersecting; the first the most common direction.
School-house	"	S. 32° E.	
Derry,—north part	Mica schist	S. 22° E.	
Below hotel	"	S. 24° E.	
South part	"	S. 22° E.	
Chester,—W. S. True's	"	S. 51° F.	
H. Hazeltine's, hill-top	Gneiss	S. 31° E.	
C. Chase's	Mica schist	S. 29° E.	Abundant.
Auburn,—west of village	Gneiss	S. 26° E.	
D. Ball's	Mica schist	S. 21° E.	
Pelham,—near west line	Gneiss	S. 21° E.	
Londonderry,—Mammoth road, N. part	Mica schist	S. 21° x 41° E.	Intersecting.
North-west part	"	S. 21° E.	
"	"	S. 11° E.	
Hudson,—Mrs. Barrett's, east part	Gneiss	S. 3° E. x S. 21° x 36° E.	Intersecting.
Nashua,—Merrimack river bridge	Merrima'k schist.	S. 11° E.	
Reservoir	"	S. 11° E.	
Merrimack,—Souhegan village	Gneiss	S. 16. E.	
Amherst	"	S. 14° E.	
Goffstown,—Centre	Granite	S. 21° E.	
N.E. part, near G. B. Blaisdell's.		S. 20° E.	W. Upham.
New Boston	Gneiss	S. 23° E.	
West edge	"	S. 11° E.	
North of Joe English hill	"	S. 16° F.	
D. Todd's	"	S. 11° E.	
Near Leach's	"	S. 9° E.	
Francestown,—north-west part	"	S. 21° E.	
Weare,—top of Mt. Misery	Andalusite schist.	S. 16° E.	
50 feet down east side	"	S. 21° E.	
Two places at south base of do.	"	"	
Hodgdon's soapstone quarry		S. 31° E. x S.	Intersecting; the first course the most common.
⅔ mile south-east of So. Weare church—A. L. Hadley's		S. 10° E.	W. Upham.
Deering,—north-west part	Gneiss	S. 19° E.	
West of village	"	S. 31° E.	
Hillsborough,—near north line	Porph. gneiss	S. 26° E.	
Antrim,—west part	"		Fine example; moved up hill in North Branch valley.
Peterborough		S. 16° E.	
J. Mace's, 3 miles east of village.		S. 10° E.	W. Upham.
Lyndeborough,—near "hard" drift.	Mica schist	S. 41° E.	Both wall and floor surfaces striated.
Wilton,—north-east corner	Gneiss	S. 21° E.	
West Wilton	"	S. 31° E.	
Temple,—top of Temple mountain	Mica schist	S. 16° E.	
North of hotel	Quartzite	South.	
Mason,—north-east corner	"	S. 36° E.	
West of centre	Gneiss	S. 11° E.	Polished smooth.
Centre village	"	South.	
New Ipswich	Mica schist.	S. 11° E.	
South end of Kidder mountain	"	S. 36° E.	
Barrett Mountain range, near W. Shattuck's	"	S. 16° E.	
W. Young's	"	S. 33° E.	
1 mile east of Wilder village	"	S. 25° E.	W. Upham.
Sharon		S. 21° E.	
Nelson,—¼ mile south of Munsonville	Gneiss	S. 20° E.	W. Upham.
Sullivan,—south-west corner	"	S. 30° E.	"
Marlborough,—⅔ mile west of Pottersville	"	S. 15° E.	"
D. Field's, 2 miles east of depot.	"	"	"
Troy,—village	Montalban	S. 21° E.	
Generally	"	S. 18°–25° E.	C. T. Jackson.
Surry,—Bald hill	"	S. 23° E.	
Gilsum,—near village	"	S. 21° E.	
Marlow,—3 miles north of village	Gneiss	S. 10° E.	W. Upham.
⅔ mile south of do.	"	"	"
Stoddard,—west line	"	S. 21° E.	
Near village	"	S. 16° E.	
East line	"	S. 21° E.	
1 mile west of village	"	S. 25° E.	W. Upham.
1½ miles west of Centre pond	"	S. 15° E.	"
1 mile south of last		S. 15° E.	"
South-west corner		S. 20° E.	"

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Harrisville	Gneiss	S. 28° E.	
Dublin,—generally	Porph. gneiss	S. 27° E.	C. T. Jackson.
1 mile N.W. of Monadnock lake.		S. 50° E.	W. Upham.
¼ mile south-east of W. Spalding's		S. 50°–60° E.	"
Keene,—north edge	Gneiss	S. 15° E.	
Hill west of village—West mt.		S. 20° E.	
West Keene, top of hill—Connecticut river water-shed		S. 15° E.	
Chesterfield,—Bear hill	Mica schist	S. 10° W.	
1 mile south of Factory village		S. 10° E.	W. Upham.
1 mile east of Centre	Mica schist	S. 20° W.	"
North of T. A. Stoddard's	"	S. 10° W.	"
Winchester,—4 miles N. N. W. from village	Porph. gneiss	S. 5° E.	"
Westmoreland,—"Hill" village	Mica schist	S. 5° W.	"
⅔ mile east of E. W. depot	Gneiss	S. 10° E.	"
Walpole,—½ mile south-east of S. H. No. 13		S. 15° E.	"
2 miles east of village	Mica schist	S. 15° W.	"
Alstead,—1 mile north of E. Alstead.		S. 10° E.	"
Hinsdale and neighborhood	Gneiss	S. 10° W.	
Depot	Mica schist	S. 10° E. x S. 60° E.	Intersecting.
North-west base of Stony mt	Mica schist	S. 2° E.	C. T. Jackson.
Richmond,—east part	Gneiss	S. 25° E.	
Soapstone bed		South.	
Fitzwilliam,—1 mile east of village	Gneiss	S. 20° E.	
Quarry hill, south of depot	Granite	S. 10° E.	Up hill.
Rindge,—East Rindge		S. 15° E.	W. Upham.
Washington,—north part	Porph. gneiss	S. 21° x 41° E.	Intersecting.
Lovell's mountain—top	"	S. 36° E.	End of ledge embossed.
1 mile south of Miller pond	Gneiss	S. 30° E.	W. Upham.
South of Ashuelot pond	"	"	"
West " "	Porph. gneiss	S. 25° E.	"
Lempster,—Lempster mount'in—top.	Mica schist	S. 41° E.	Uncommonly fine.
West side do	"	S. 21° E.	
Acworth,—village	"	S. 8° E.	The same 1 mile west.
Charlestown,—village	Coös schists	South.	
East part	"	S. 11° E.	
Near north-west Acworth		S. 5° E.	W. Upham.
Unity,—south of Neal mine	Mica schist	S. 51° E.	
Centre	Gneiss	S. 10° E.	W. Upham.
East Unity	"	"	"
Claremont,—aqueduct, north slope of Bible hill	Slate	S. 17° E.	
Top of Bible hill	"	S. 6° E.	Noticed more fully in text.
Below top	"	S. 1° W.–S. 57° E.	
Most common about village	"	S. 41° E.	
1 mile south-east from Claremont village		S. 25° E.	W. Upham.
¼ mile north do		S. 15° E.	"
Barber mountain, south-west side, near J. Woodell's	Huronian	S. 12° W.	
Barber mountain—top	"	S. 16° W.	
A. Brown's, W. Clark's, and south of N. Stone's	Mica schist	S. 12° W.	
S. Nott's		S. 23° E.	
East of S. Nott's		S. 13° E. x S. 47° E.	Intersecting, and irregular below.
L. Farnsworth's		S. 11° E. x S. 76° E.	Intersecting; first cut by second.
West of C. Dean's		S. 46° E.	
Cornish,—west flank of Croydon mountain—Hilliard's	Slate	S. 19° E.	
4 miles south-west from "Flat"		S. 20° E.	W. Upham.
Goshen,—south part	Gneiss	S. 21° E.	
Croydon,—south end of Croydon mountain	Coös schists	S. 31° E.	Boulders in a line, S. 40° E.
Plainfield,—north end Croydon mt		S. 20° E.	W. Upham.
Grantham,—½ mile south-east from last		S. 30° E.	"
New London,—east end of Otter pond	Gneiss	S. 30° E.	"
1 mile east of do	"	S. 40° E.	"
Springfield,—Mud pond	Gneiss	S. 51° E.	Very fine.
J. Currier's—ridge	"	S. 21° E.	Numerous.

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Ridge	Gneiss	S. 29° E.	
1½ miles north-west of West Springfield	“	S. 6° E.	
Station pond	“	S. 37° E.	
South line next George's mill	Andalusite schist.	S. 31° E.	
A. Melvin's	Gneiss	S. 26° E.	Top of hill near, S. 20° E., on quartz veins beautifully smooth.
Grafton,	“	S. 25° E.	
Mica quarry—Ruggles's	Mica schist	S. 31° E.	
Miners' house—Ruggles's	“	S. 21° E.	
Hill north	“	S. 31° E.	
Outlet of Tewsbury pond	“	S. 31° E.	Uncommonly fine embossment; valley movement.
North end of do	“	S. 36° E.	
Melvin's mica quarry	“	S. 34° E.	
Grafton,—school-house No. 3	Gneiss	S. 31° E.	
C. Prescott's—hill-top	“	S. 41° E.	Observed in two places.
Hill west of Prescott's	“	S. 46° E.	
V. W. Powell's, west side of hill.	“	S. 31° E.	Transversely up hill.
Near top of Alger hill	Granite	S. 41° E.	
Giles's pinnacle, west side	Gneiss	S. 25° E.	
Orange,—summit	Mica schist	S. 36° E.	Grooves.
Between school-house No. 1 and church	“	S. 21° E.	
Andrews's mill	“	S. 31° E.	Abundant.
Hoyt hill, south of quarry	Andalusite schist.	S. 31° E.	
“ mica quarry, N. side	“	S. 31°–36° E.	Striæ visible for 50 feet and furrows.
Top of Shad hill		S. 17° E.	Very fine.
Canaan,—1 mile west of Orange summit	Gneiss “	S. 31° E.	
Hill north-west of East Canaan	“	S. 26° E.	
North-east of Hart's pond	“	“	
Sawyer's hill	“	S. 21° E.	
South edge	“	S. 24° E.	
North line	“	S. 11° E.	
Enfield,—1 mile east of village, on lake	Lake gneiss	S. 21° E.	
West side of ridge, near W. line.	Coös slates	S. 24° E.	
Lily pond	Quartzite	S. 21° E.	
West of do., ¼ mile	Mica schist	S. 16° E. and S. 61° E.	Intersecting.
South-west base of Choate hill	Gneiss	S. 26° E.	Up hill, and east side of rocky valley.
East hill, east side	“	S. 24° E.	
Lebanon,—east edge of village	“	S.	
West of East Lebanon	Quartzite	S. 21° E.	
West of B. Walker's	Slate	S. 51° E.	On ledges close by course is S. 7° E.
D. Hardy's	“	S.	
Near hill-top further north	“	S. x 21° E.	Intersecting.
East Lebanon	“	S.	
School-house by O. S. Martin's	Mica schist	S.	
Between A. Freeman's and H. Grant's	Coös slate	S. 7° E.	Abundant.
Hanover,—near S. H., Hayes's hill	Clay slate	S.	
West part of do	“	S. 31° E.	
North part of do	“	S.	
Hill south from S. Hayes's	“	“	
Near town line to south	“	“	Embossed ledges 40 feet long.
A knob west	Quartzite	S. & S. 21° E.	Latter on lee side of first; do not intersect.
Copper mine, “ Rudsborough ”	Mica schist	S. 9° W.	
Mink brook, near Held. conglomerate	Slates	S. 51° E.	Unusual; local (?).
Enfield side of Moose mountain, near school-house	Gneiss	S. 19° E.	
W. K. Covell, hill-top, N. part	Mica schist	S. 11° E.	
Observatory hill	Hornblende sch't.	S.	Obscure.
Moose mountain		S. 38° E.	J. H. Huntington.
Lyme,—below I. P. Holt's, down valley from East Lyme to Canaan	Gneiss	S. 31° E.	
A. Blood's, down valley from East Lyme to Canaan	“	S. 26° E.	
West of I. F. Clark's	“	S. 26° E.	
L. Conant's, east part	“	S. 21° E.	
West of S. Ames's		S. 11° E.	
Orford,—top of Mt. Cuba	Quartzite	S. 28° E.	Abundant.
West side	Staurolite schist.	S. 37° E.	
Top of Sunday mountain	Mica schist	S. 11° W.	
Few rods on south slope	“	S. 3° W.	
Cheese factory	“	S. 2° E.	
Bass hill—top	“	S. 8° W.	
Near C. Albee's, north part	“	S. 14° E.	Very fine.

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Bridgewater	Montalban	S. 32° E.	Down valley.
Dorchester,—south part	Gneiss	S. 12° E.	
Wright's hotel	"	E.	
2 miles south of village	"	S. 17° E.	
Piermont,—east part	Hornb. schist	S. 42° E.	
½ mile west	"	S. 24° E.	
West part, near Conn. river	Huronian	S. 15° E.	
1 mile east of village	Mica schist	S. 18° W. x S. 22° E.	Intersecting.
Near whetstone quarry	"	S. 19° E.	On large hill.
East part of town	"	S. 20° E.	
North of Tarlton pond	Gneiss	S. 18° W.	Near foot of Webster Slide mountain.
Peaked Hill range to south	Mica schist	S. 16° E.	
Cross hill	Quartzite	S. 42° E.	C. T. Jackson.

STRIÆ IN STATES CONTIGUOUS TO NEW HAMPSHIRE.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
VERMONT.			
Norwich, Vt.,—east of school-house No. 2, and also below Dutton's, a mile distant	Clay slate	S. 26° E.	Down a valley tributary to Conn.
D. H. Bragg's, Distict No. 2	"	S.	Normal course again, west of the local one above.
Gregg's hill	Calc. mica schist.	S. 8° E.	Numerous.
Weathersfield,—near Conn. river	Huronian	S. 4° W.	
South of do	Slate	S.	
Opposite North Charlestown	"	"	
Warren,—Summit to Roxbury	Huronian	S. 31°–41° E.	Intersecting.
Near do	"	S. 55° E. & S. 60° W.	"
Sherburne	Gneiss	N. 10° E.	Down hill.
Windsor,—top of Mt. Ascutney	Sienite	S. 20° W. S. & N. 80° E.	
¾ way down	"	S. 10° E.	
At dam near village	Mica schist	S. 30° E.	The common direction.
" "	"	N. 70° E.	Unusual direction, and local.
Bradford,—south-east corner	Huronian	S.	
Peacham,—1 mile west of "Corner".	Granite	S. 13° E.	
Canaan,—2 miles west of Conn. river.	Mica schist	S. 34° E.	
OBSERVATIONS TAKEN BY GEOLOGICAL SURVEY.			
Waterbury,—east part	Huronian	S. 41° E.	
Stowe,—central parts	"	S. 35° E.	
Elmore	"	S. 24°–38° E.	
Woodbury	"	S. 12°–S. 42° E.	The observations taken in these several towns were abundant, and I have given the extremes, it being unnecessary to present all the details of locality and variability.
Barnet and Waterford	"	S. 7°–12° E.	
West Concord	"	S. 22° E.	
East Concord	"	S. 2° E.	
Kirby	Slate	S. 20° E.	
Lunenburg	Huronian	S. 13° E.–S. 28° E.	
Guildhall	"	S. 7° E.	
Granby	Mica schist	S. 13°–33° E.	
Victory	"	S. 23° E.	
Maidstone	Mica schist	S. 23°–41° E.	
Canaan	"	S. 13°–25° E.	
Sheffield	Calc. mica schist.	S. 4° E.	
Glover	"	S. 7° E.	
Greensborough	"	S.–S. 12° E.	
Craftsbury	"	S.	
Lowell	Huronian	S. 22° E.	
Wolcott	"	S. 57° E.	Runs up Lamoille valley.
Hyde Park	"	S. 4°–37° E.	
Morristown	"	S. 18° W.–S. 7° E.	
Johnson	"	S. 42°–82° E.	Up Lamoille valley.
"	"	S. 8° W.	Normal course.

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Mansfield mountain	Gneiss	S. 22° E. and S. 57° E.	
Jay peak	“	S. 53° E.	
Camel's Hump	“	About S. E.	
Troy	Huronian	S. 28° E.	
Salem	Mica schist	S. 23° E.	
Brownington	“	S. 12° W.	
Brighton	“	S. 13° E.	
Randolph	Huronian	S. 8° W.-S. 52° E.	
Roxbury	Mica schist	S. 8° W.	
Newbury	Huronian	S. 15°-37° E.	
Bradford	“	S. 22°-32° E.	
Fairlee	Clay slate	S. 9°-17° E.	
Thetford	Mica schist	S. 12° E.	
Chester	Gneiss	S. 42° E.	
Rockingham	Clay slate	S. 2°-11° E.	
Putney	“	S. 10°-2° W.	
Dummerston	“	S. 10° E.	
Brattleborough	“	S. 10°-18° E.	
Vernon	“	S. 4°-22° E.	
Guilford	“	S. 10°-15° E.	
QUEBEC.			
Aukland	Argillac. schist	S. 24° E.	J. H. Huntington.
Gould	Mica schist	S. 60° E.	“ “
Newport	Calc. mica schist.	S. 34° E.	
Sherbrooke	Huronian	S. 22° E.	
Sutton	“	S. 36° E.	W. E. Logan.
Sutton Flats	“	S. 26° E.	
Orford	“	S. 43° E.	“
Brome,—Canada mine	“	East.	
East Canada mine	“	S. 18° E.	
Jerry Davis's	“	S. 13° E.	
Potton,—top of ridge south of Owl's Head	“	About E.	
MAINE.			
Portland,—north-west from custom-house	Huronian	S. 23° E.	Very fine.
Portland hospital	“	S. 3° E.	
Saco	Cambrian	S. 16° E.	
Lebanon post-office	Andalusite schist.	S. 47°-52° E.	
East of Lord's	“	S. 47° E.	Very fine.
Springvale (Sanford)	Mica schist	S. 42° E.	
Denmark village	Gneiss	S. 12° E.	
1 m. north of Pinhook, Bridgeton	“	S. 32° E.	
Bridgeton, north-west of village	“	S. 20° E.	
Standish, railroad lake station	Mica schist	S. 22° W.	
Top of Mt. Pleasant	Granite	S. 41° W.	
West side, near top	“	S. 31°-33° E.	
Androscoggin valley, north part of Mt. Ephraim	Montalban	S. 64° E.	Androscoggin Valley marks more fully described in text.
Church in Gilead, north side	“	S. 73° E.	
Base of Tumbledown-Dick	“	S. 83° E.	
East line of Gilead	“	S. 58° E.	
Paradise hill, Bethel	Gneiss	S. 23° E.	
Newry	Montalban	S. 33° E.	Down Bear River valley.
Falls near Poplar tavern	“	S. 19° E.	
Just above do	“	S. 34° E.	
East line of Grafton		S. 84° E.	
Grafton notch—highest point	Mica schist	S. 14° E.	
Upton,—D. C. Brooks's	“	E. of S.	
O. H. Abbott's	“	S. 59° E.	
Near East B. hill	“	S. 47° E.	
Opposite Dartmouth College grant	“	S. 4° E.	Valley movement down the Magalloway.
Andover N. surplus, n'r Dunn's notch.	Granite	S. 64° E.	
A. Pratt's	Gneiss	S. 64° E.	
South line	Mica schist	S. 34° E.	Valley movement.
N. S. Lufkin's	“	S. 24° E.	
J. Howe's	“	S. 34° E.	Curving with valley.
Rangely,—top of Bald mountain	Granite	S. 64° E.	J. H. Huntington.
Bethel,—opposite Hanover	Gneiss	S. 4° E. and S. 14° E.	
Near Songo pond	“	S. 44° E.	
Lovell,—No. 4 Corners	“	S. 8° E.	
Fryeburg,—Near Mt. Tom	Granite	S. 32° E.	

Courses of Striæ—Continued.

LOCALITIES.	ROCK.	TRUE COURSE.	REMARKS.
Broomfield,—M. McLucas's	Granite	S. 18° W.	
Hiram,—north west of Spectacle pond	Gneiss	S. 12° E.	
Cornish,—Ossipee river, above village	Montalban	S. 22° E.	
Standish,—west edge	"	S.	
Limington,—W. Chick's, east base of hill	Andalusite schist.	S. 52° E.	
F. Strout's, top of hill	"	S. 33° W.	Several examples of this remarkable direction occur for ½ mile.
Limerick village	"	S. 22° E.	
Alfred,—½ mile north of N. Alfred	"	S. 32° E.	
J. Roberts's		S. 32° E.	
South Berwick		S. 32° E.	
Danville junction, G. T. R.		W. of S.	On wall—well shown.
Saco slate quarry	Cambrian	S. 15°-20° E.	
Cape Elizabeth,—T. Seavey's	Huronian	S. 8° W. and S. 22° E.	S. 8° W. course the most common.
Edge of	"	S. 27° E.	
Peak's id.,—Evergreen landing	"	S. 22° E.	
East side	"	S. 37° E.	
Cape Elizabeth,—Rail schist locality.	"	S. 12° E.	
Deering,—hospital		S. 2° E.	
MASSACHUSETTS.			
Northfield,—very near New Hamp	Mica schist	S. 8° W.	
New Salem,—top of hill	Gneiss	S. 12° W.	
South Royalston	"	S. 10° E.	
Salisbury,—Eastern Railroad crossing north of village	Sienite	S. 51° E.	
Bernardston,—top of West mountain.	Slate	S. 5° E. x S. 10° E.	
Newbury,—several places	Sienite	S. E.	According to Massachusetts report.

Remarks. The table contains everything needful for explanation, save where more than one set of striæ is mentioned. When two or more sets occur in immediate contiguity, not crossing each other, the fact is indicated by the use of the conjunction *and;* when two or more intersect each other, the letter *x* is employed, and the fact is usually stated in the column of remarks.

The embossment of certain ledges in Pittsburg and Shelburne is peculiar, in that the lower part of the rock below the smoothed surface is rough. The ice may not have struck the lower part of the ledge; or, in some cases, the subsequent disintegration may have removed the lower part, leaving it as rough as the lee side. The Pittsburg examples may be eight or ten feet high, with a roughness of three feet, partly to be accounted for by the easy removal of rock on account of the presence of easterly dipping jointed planes. The Shelburne example is more striking. It is about a mile below the station. The ledge is about 30 feet high and 75 long, and the roughness below the striated part as much as 6 feet. The irregularities upon the lee side begin at the very top of the eminence. The end struck is 40 feet wide, tapering to a blunt point, where the smoothed appearance disappears; and the inclination of the stoss slope towards the north-west is about 50°.

Wall and floor surfaces are alluded to. This is because some writers insist that the former method of sculpture is never seen with iceberg action, being produced only by a glacier. As noted above, this species of moulding is very common.

The striæ about Bible hill in Claremont need further mention. This hill rises about 350 feet above the plain of the village at its northern base. What is supposed to be the normal direction is about S. 12° W., which occurs commonly west of the summit of the hill for two or three miles, reaching beyond the Connecticut. North of the village, it is S. 15° E.; among the houses, S. 41° E.; and on the east side of the hill, S. 23°–25° E., in a valley leading to Unity. On the south slope of Green mountain, east of the village, are intersections of the almost east course with that of about S. 12° E. On the westerly side of the top of Bible hill the most common course is S. 6° E. with S. 25° E. This is half a mile east from Brown's, Clark's, and Stone's, where the westerly course has been noted. We now proceed three fourths of a mile north-east to the "Flat Top," a spur of the hill, with scarcely any depression between. At the commencement, where the north-east slope begins, are striæ S. 57° E. pointing back to Little Ascutney, and crossing others S. 1° W. Next are some S. 46° E., pointing to Ascutney, apparently marked on the lee side of striæ pointing S. 1° W. to S. 1° E. Another ledge has striæ S. 46° E. crossed by others S. 1° E.; then S. 16° E. crossed by S. 41° E. and S. 51° E., the middle one the most common. Another ledge shows, in a narrow compass, the courses S. 21°, 36° 41°, and 57° E. Where the courses are so numerous, there is a marked tendency to irregularity; the striæ do not preserve their parallelism. A change of ten or fifteen degrees in direction will occur in a distance of less than a yard. Flat Top hill shows more of the irregularities than the highest summit to the south-west. Near the aqueduct, at the base of Flat Top, the course is S. 17° E. The impression was acquired at our visit that the south-east course cut those running southerly.

This is the most remarkable mingling of striæ I have ever met with. It is obvious that the field was crossed by the ice proceeding south-east and south, or from Ascutney, and down the Connecticut. The first were also occasionally deflected still more to the east by the large valley of Sugar river leading easterly to Sunapee lake. Some of the intermediate courses might have been caused by the meeting of the two masses of ice struggling to advance in different directions. Boulders from Mt. Ascutney are common to the north-east and east of Bible hill. The locality needs further exploration.

A few other interesting localities will be mentioned next before we attempt to draw the legitimate conclusions authorized by the list of striæ.

Mt. Monadnock.

This mountain possesses a conical shape, rising about 2,000 feet from a comparatively level country, the elevation of the plain being 1,000 feet above the sea. Its composition causes the striæ and embossment to be well preserved, while its isolated position illustrates one peculiarity of the drift-action. My father first described it in the *Proceedings of the American Association of Geologists and Naturalists,* in 1842, in the geology of Massachusetts, and in his text-book. He says of it,—"From top to bottom it has been scarified on its northern and western sides. On its lower parts, especially on the south-west side, the striæ run about N. W. and S. E., by the magnetic needle, as they do in the country around the mountain; but, when we approach its top, the course changes to N. 10° W. and S. 10° E. Other striæ are seen here on steeper slopes, both northern and southern, than I have found elsewhere."

The observations given in the table were mostly taken in 1871. It would appear that the common direction in the vicinity of Monadnock is about S. 12° E., the towns north showing a few degrees additional of easting, while the mountain itself, from the lake to the south-west corner of Jaffrey, about eight miles, exhibits, on its north-west flank and southern edge, the south-east course. After looking over the whole area, one sees that the ice coming from the north and west of north struck the mountain and clung to it closely, so much so as to run much more easterly on the south edge than elsewhere. Over the region to the south-east all trace of this easting is lost, the striæ in Jaffrey running S. 11° E., much like those of Troy and Marlborough. I have not explored the east side of the mountain; it is mostly covered by trees. Hence it is impossible to decide upon the value of Mr. Wheelock's theory, from present explorations. I understand his view to be, that Monadnock was an island in a sea full of icebergs, which struck equally strong upon both the north-west and south-east sides. There is certainly a dearth of striated ledges upon the south-east side, while even the earth has been largely removed from the north-west flank, so mighty has been the planishment of the rock. The striæ on the south-east side should all point south-westerly, if the summit were an island scarified on both sides by icebergs. Mr. Wheelock's paper is a very valuable one; and that part which relates to striæ is herewith reproduced.

Striæ on Mt. Monadnock.[*] Having, in the last three years, spent many days in studying the striæ upon Mt. Monadnock, the writer is unwilling that the results of his observations should be lost for want of record, especially as they seem to have an important bearing upon unsettled questions of surface geology. This mountain is peculiarly favorable to such study. Its long spurs radiating from a central elevation, though less regular than the points of a star, yet present to four points of the compass long ranges of bare rocks, which have recorded the markings of the ice-period, with all their variations of direction, and furnish a lesson not to be found, perhaps, in any other locality. To understand fully the meaning of the evidence herein detailed, it is necessary to have a clear idea of the relative bearing and position of these radiating ridges or spurs.

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[*] *American Naturalist*, vol. vii, 1873.

For the sake of clearness of description, we will suppose the principal ridge, which runs N. 25° E., to be straight, and to be four miles long. This ridge was an uplift, sloping towards the west, and presenting its broken and precipitous face towards the east. It is like a dam set obliquely across the current of the northern drift, and its serrated edge rises from 1,500 to 2,000 feet above the surrounding country, growing higher from each end to its central parts. If we suppose a section of this range near the centre to be pushed some fifty rods further west, and elevated to the height of 3,280 feet, we shall have the summit of Monadnock. A short spur projects west of the summit about a mile, and divides into two branches. These we will call the west and north-west spurs. The two ends of the dam we will call the north and south spurs; these, with the western spur and its north-west fork, complete the outline of the mountain, making four radii.

Numerous observations of the direction of drift striæ made in the adjoining towns show very general uniformity. They have a range of not more than 15°, varying 15° west of north to north and south. On the summit of Monadnock the direction varies within the same limits. Only one set of striæ was noted there as 5° east of north. So, too, following along the north-east spur, there is no change in the striæ so long as the altitude remains the same. The crest is all naked rock for two and a half or three miles, and frequent observations can be made. Just as fast as the ridge falls off in height, the striæ gain a more westerly direction, becoming 15°, 20°, and 25° west of north; where the rocky ridge terminates and is succeeded by open pastures, 30°, and in many places 40°, were noted as common. Appearances indicated a local deflection of a current around the northern end of this long dam.

Although a special expedition was made to what was called the north-west spur, the lower portion of it was so much covered with drift that few exposed places could be found. Some five or six, however, and all that were noted, showed striæ N. 25° E. All the higher portions of the ridge were striated like the summit and the ridge before described.

Another day's expedition was made to the west spur. Standing on the crest of this lofty ridge, and looking towards the south, the view is unobstructed to the horizon. The striæ all along this ridge are innumerable, and all north and south. There is no opposing ridge near, to lead one to expect south of this a change in the striæ. On the contrary, there is every facility for the drift current after passing this ridge to continue on in a straight course. The southern spur is a mile or more off on our left, and presents a high opposing barrier towards the south-east, but none towards the south. Why should the drift current, after passing this ridge, suddenly turn towards the east and climb the steep and lofty barrier of the south spur? Nevertheless, there are indications of just such a change as this.

If we place one foot of a pair of imaginary compasses on the summit of Mt. Monadnock, and with the other strike a curve from the west spur to the south spur, we shall hardly have made a more complete change of direction from one spur to the other than is indicated by the striæ in the short space of a mile and a half. It is difficult to pass over all parts of the valley between these two spurs, the upper portion of it being extremely craggy or uneven. It is better to go down to the open pastures at the base of the mountain. Beginning at the foot of the western spur, and skirting the base of the mountain towards the east, the first thing to excite attention is the immense number of boulders. They exceed in multitude any other deposit about the mountain, but form no part of its talus, which does not fall on this side. They seem to be in some way connected with the change of the drift current, which began at this place, and with the position of the ridge, under the lee side of which they lie. Passing through these boulders, which continue for half a mile or more, we come to the first bare ledges. These are marked with striæ N. 20° W. These are soon succeeded by others, 30°, 40°, and 50° west of north. They may not all occur in regular order. On some ledges there are two or three sets of striæ of different angles. Proceeding a mile and a half, we arrive at the easterly slope of the south spur, near the Mountain house. The road to this house was built north and south on sloping ground; and for half a mile the fresh surface of the rock was in many places exposed to view. It is everywhere scratched and polished. These scratches vary from 50° to 60°, and 70° west of north. Climbing the slope of the ridge, everywhere the exposed prominences of rock are embossed in the same direction. Arriving at the crest of the ridge, it is everywhere serrated and uneven.

On this height we again overlook the whole country. Here, on the narrow crest of the ridge, the striæ are very generally N. 40° or 45° W. In one place an angular trough, perhaps 20 feet long and 6 feet deep, runs across the crest. In this are long, continuous striæ due east and west. They appear to be exceptional, and suggest the idea that this shallow trough had been able to control and change the direction of the striating force. Standing on this ridge, and looking towards the east, we see that the mountain on this side is very precipitous, and that probably there are no striæ on its broken surface. Higher up the mountain, within a thousand feet of the summit, the striæ are 35° and 30° west of north; lower down, at the extremity of the south spur, the end of the long dam, they vary from 40° to 25° west of north. What kind of striæ should we expect to find under the lee of this four-mile breakwater? Another expedition and another day were required to answer this question. The country east of the four-mile ridge is mostly wooded and difficult to traverse. The rock is mostly covered by drift. Beginning at the south end, and travelling north, no striæ were found until two thirds of the distance had been passed over. Curiosity was at last gratified by finding large, flat surfaces of naked rock, scored all over with long parallel lines much better preserved than those on less wooded and more exposed parts of the mountain.

It would be difficult to decide what was their prevailing direction. Multitudes ran due east and west; some few, north and south; some, N. 10° W.; some, N. 10° E.; many, N. 70° and 80° W.; many, N. 70° and 80° E. No theory of mountain slides could explain this remarkable scratching: the situation seemed to forbid such an explanation. These observations were made on many different ledges, but all of them within half a mile of each other, and within a mile of the north end of the ridge. When a rapid stream, with a current of three miles an hour, passes a rock in its bed, water will flow around the rock and meet on its lower side. Do not these irregular striæ indicate a changeable and eddying current inconsistent with the motion of a glacier?

MTS. KEARSARGE AND RAGGED.

Mts. Kearsarge and Ragged rise abruptly from a comparatively level country, like Monadnock, but, being situated near each other, not quite six miles apart, the conditions gave rise to a different motion of the ice. Ragged is not so completely isolated as Kearsarge, being connected with mountains in the north part of Andover. Sutton, Salisbury, and Hill have the average direction for striæ of about S. 12° E., while in Warner there are several degrees more of easting. The parts of Wilmot and New London next to Kearsarge do not show striated ledges. Starting from Warner, on the south, the table shows the change from S. 20° E. to as high as S. 76° E., it being nearly south-east on the summit. On following down the north side, the easting falls off to S. 36° E. at the Winslow house, but reaches N. 67° E. in the valley by Potter Place. Similar figures continue all the way to the top of Ragged mountain from the southern base. At the last house,—1,100 feet (450 feet above Potter Place),—the striæ run S. 71° E.; at 1,340 feet elevation, S. 31° E.; at 1,650 feet, S. 46° E.; at 1,775 feet, S. 23° E.; the same for 200 feet further; at 2,000 feet, S. 36° E.; at 2,100 feet, S. 23° E. and S. 51° E. Here the embossed ledges are numerous, while the striæ are much worn. The S. 50° E. course appears higher up, but not on the summit or at the signal, 2,256 feet, where the direction S. 23° E. is to be seen. We have, therefore, two well marked directions, very much as on Monadnock, the S. 23° E. course appearing by itself on the summit, while the south-east lines show themselves all the way down the south slope.

Considerations will be presented soon, showing that there was somewhat of a local or valley movement of ice down the Blackwater river. It may be that the greater eastings of the striæ about Potter Place are due to other causes than the mere influence of the two mountains, so that we cannot strongly insist that the easterly movement of the striæ from Hill to Warner is entirely due to the presence of the two mountains. The only feature where this case is unlike Monadnock, is the easting at the base of the mountain, which we see may have been produced by an independent movement.

Other Mountains similarly Striated. Of other mountains similarly situated, some exhibit the same kind of ice-action. Mt. Gunstock has S. 62° E. striæ on top, and the S. 32°–35° E. course on the east side, bordering Lake Winnipiseogee. Mt. Lovell in Washington shows the direction S. 36° E. on the summit, while it is commonly S. 21° E. in the north part of the town, though crossed by a set running S. 41° E. Lempster mountain summit shows the direction S. 41° E., and it is S. 21° E. on the west side. On Mt. Cuba we find S. 28° E. and S. 37° E., while it is commonly west of south in Orford on the west, and S. 22° E. in Wentworth. Moose mountain in Hanover shows S. 38° E. on its summit, while the course is south on the western side, and S. 19° E. on the Enfield side. There is a south-east course in the middle and south-east part of Hanover, which may have some connection with these movements on the elevated summits. Sunapee mountain would be expected to agree with its neighbors, but no observations of striæ have been made there. Mt. Ascutney, just out of the state, exhibits phenomena worthy of mention here. This has the same altitude with Mt. Monadnock, while the land about it is more uneven, averaging less than around the Cheshire peak. Owing to the rapid disintegration of the rock, striæ are scarce, and perhaps the few examples discovered should not be taken as truthfully representing the general courses. The very summit showed a due south course. About 300 feet lower down, on the north-east side of the mountain, following the Windsor path, are striæ running due east, or N. 80° E. They rest upon a wall inclined 70° N., and point down the mountain towards the south part of Cornish. Others in the neighborhood run S. 20° W. About two thirds of the way down are other distinct striæ running S. 10° E.; and no others were seen on the mountain proper. On reaching the dam over Mill brook, west of Windsor village, the course S. 30° E. is seen, and a few N. 70° E., a very unusual direction, supposed to have been the result of some local disturbance. In Weathersfield and Claremont, along the river, the usual course is west of south. Observations west of Ascutney are wanting. It appears, therefore, that the observations are not ample enough to say positively, though it is probable, that the striation of Ascutney is like that of Monadnock.

Mt. Pleasant, in Denmark, Me., may also be mentioned as allied to Monadnock. South of the mountain the course is S. 12° E.; east, it is S. 20° E.; north, it is S. 8° E., while one observation in Fryeburg, to the west, reaches S. 32° E. On the summit the striæ run S. 41° E. On the north-west side, following down the path, good examples occur of the course S. 31°–33° E. Lower down are others less satisfactory, running S. 52° E. Not far from the Half-way house are some seemingly local, running west down the hill.

Certain other elevations in the state, with topographical surroundings like Monadnock, show little difference in the direction on the summit and the neighboring plain. Such are the Moose mountains in Brookfield and Middleton, Teneriffe in Milton, New Durham ridge, Catamount hill in Pittsfield, Blue hills in Strafford, Saddleback in Northwood, Temple mountain, Barrett mountain in New Ipswich, etc. Crotched mountain in Francestown, Ossipee in Carroll county, and Pawtuckaway in Nottingham, have not been studied, while Green mountain, Effingham, is too thoroughly disintegrated to preserve any markings.

PREDOMINANT COURSES OF STRIÆ.

The Vermont geological report states that the striæ may be classed in three divisions,—those pointing to the south-west, south, and south-east, the first being the least common. The south-west course is much more infrequent in New Hampshire, while the south-east direction is more prevalent than in Vermont. A sketch map in Volume I (p. 542) shows the general relations of these three kinds of movement for both states. Many of the striæ are so disposed that they may be believed to be the result of valley movements. In our researches we have constantly asked, How much do topographical features influence the course of the striæ? The replies forced upon us insist that a portion of the directions is due to topographical features, while others—the majority—pursue a fixed course, in total disregard for all obstacles. The first we have styled valley movements. A part of these are distinguishable from the others where the course of the valley corresponds with that of the neighboring striæ.

The south-east courses commonly occur upon the most elevated mountains, both in New Hampshire and Vermont. The whole Green Mountain range, and the loftier Presidential line of White Mountain summits, show this direction of marking. Scarcely any other course is known in Coös county, and it is common all through the Lake and Coast districts, including Essex county, Mass., and all the mountains of the Monadnock type. On comparing these courses over so much of New England with the customary south-east course of the valley of the St. Lawrence, one perceives a very striking contrast, and has the difficult problem of the course of the south-east current set sharply before him. How could the ice-sheet climb the highest New England mountains from the low St. Lawrence valley, and then press onward to the sea? I will not attempt the answer at present, but offer, in the first place, our reasons in full for believing the ice current passed over the summit of Mt. Washington.

Evidences of Glacial Action upon Mt. Washington.

As this is the highest summit in the whole glaciated area of North America, geologists have been greatly interested in examining its sides, to note how far the ice-marks could be found. The most important visit in that regard was that of my father in 1841, and the observations then made universally accepted. Most other geologists have visited the mountain, but have had no occasion to publish anything about the phenomena. My father, in 1841, became greatly interested in drift phenomena, and visited the White Mountains for the purpose of determining the limits of the ice-action. He came from Conway through the Notch, passing up the Crawford bridle-path. "Along the whole course of the valley," he says, "I noticed rather fewer of the phenomena of drift than in most of the mountain valleys of New England." After describing the route of the path, he says,—

> All the peaks which I ascended are made up of broken fragments of this slate, which have been entirely removed from their original position by frost, and form sometimes a coating of loose angular blocks several feet thick. This is particularly the case upon the summit of Mt. Washington, and downward about 1,000 feet [see frontispiece, vol. i]; but in all the valleys between these peaks more or less of the rocks appear in place,

> and here I discovered many examples of embossed rocks. They are, as we might expect, much less distinct than in many other places less exposed to decomposing agencies, and I should probably have passed by them without recognition, had I not previously examined many other more distinct examples. So far as Mt. Clinton has been uncovered, it seems one huge boss more or less rounded. As we begin to ascend Mt. Pleasant, the embossed rocks are quite distinct; and here, too, are boulders most evidently transported. Here, too, I discovered striæ running N. 30° W., S. 30° E., corresponding essentially with the general course of striæ on the mountains of New Hampshire and Massachusetts. * * Near the south foot of Mt. Franklin is another example of the embossed rocks with boulders. * * Finally, at the south foot of Mt. Washington, near a small pond called *Lake of the Clouds*, is a third example of the *Roches moutonnes*. It is less distinct than at the other localities, as the rock here is more broken up by frost; still it is impossible for a practised eye not to recognize them. And it ought to be stated that here it is the north-west exposure of the rocks that has been most powerfully acted upon, proving conclusively that the force was exerted from that direction. * * Can there be any reasonable doubt that the rocks on the summits of all these peaks were once abraded by the same agency, and that, were they in place, they would still exhibit traces of it?
>
> *Conclusions.* In the first place, the same glacio-aqueous agency that has operated in a south-easterly direction over the northern parts of the continent, at the lowest and at intermediary levels, has acted in the same manner and in the same direction upon the summits of the White Mountains. * * Hence, thirdly, we have no reason to suppose that the White Mountains have ever been a centre from which boulders have been dispersed; and no evidence has been discovered on the sides of the mountain of the former existence of glaciers. * * * * * *

But as no ice-marks were discovered on the highest summit, my father and others could not affirm what they seemed to have believed, that the glacier did move over the summit. Every geological text-book in the land has followed the leading of the facts just stated; and it has seemed an established dictum, that no ice marks could occur above about five thousand feet.

In 1870 I traversed Mt. Washington, following the usual paths, and discovered small transported stones of a nature foreign to the mountain, at an altitude of 5,800 feet. The locality was at the then upper tank of the railway. Not much search was made, as it seemed preposterous to question the conclusions of my predecessors, though my notebook stated that the ledges above these pebbles exhibit the usual appearance of embossment produced by glacial agency, the force having come from a north-westerly direction, but no striæ were seen upon them. In the years following scarcely any thought was bestowed upon the subject; and it was almost by accident that, in 1875, I found decisive evidence to prove the passage of the glacial sheet over the summit of Mt. Washington. Very shortly afterwards the story of the discovery was communicated to the public, as follows, at the Detroit meeting of the American Association for the Advancement of Science:

> The first suggestion of this novel proposition came to me the last day of July, 1875, from an examination of the somewhat rounded stones of small size lying along the carriage-road upon the north-east side of the mountain, about two hundred and fifty feet below the summit. I stumbled upon two boulders of granitic gneiss foreign to the mountain, one nearly ten and the other six inches long. This raised the altitude at which transported materials existed to above 6,000 feet. Observation showed that these boulders came invariably from the earth underlying the conspicuous angular débris common all over the peak above the line of trees. In repairing the road, the workmen usually dug beneath the surface blocks before obtaining a material suitable for their purposes, and there always seemed to be a plenty of it. This earth proves to be the ordinary *ground moraine* of modern glacialists, full of the worn angular and roundish stones, which have been fashioned peculiarly by being shoved along. Large boulders are not common in it, though abundant elsewhere. These stones are usually of the same mica schist and gneissic rocks that compose the adjacent ledges; and this kind of ledge extends to Israel river, five or six miles distant from the top of Mt. Washington in a north-westerly direction. Were these deposits situated in the lowlands, they would be pronounced at first sight by any one to be the common drift heaps of the neighborhood. I did not discover satisfactory evidences of striation upon the few stones picked up near the two boulders of granite just mentioned, but they possess the characteristic shapes of those that are covered with scratches elsewhere. Some are pointed at both ends, being either flattened or round along the middle. Others are squarish or trapezoidal, with rounded corners. Many resemble perfectly the shapes figured by Geikie in his recent work on *The Great Ice Age;* and, in fact, they are of the constantly occurring forms familiar to all glacialists. The rock is quite soft, and that fact may explain the absence of striation.
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> The question naturally arose, as I lifted up these stones, Are these the shapes resulting from the cleavage of ledges by frost? No, it could not be; some agency of transportation other than the falling down a slope has worn off the edges, smoothed their surfaces, and mixed them with earth. The glacial ice must have transported them, though they cannot have travelled more than five or six miles, or the limit of the extent of this kind of rock. If this were so, then the whole of Mt. Washington was covered by the glacier ice. Thus I reasoned with myself, and began to look further. Remembering that these glaciated stones came from below the surface, I sought for localities where the lower earth had been excavated. The first case examined was the founda-

tion of the Mt. Washington hotel. In laying the foundation of this edifice,—nearly two hundred feet long,—the angular débris was first taken up and placed in the cellar walls. When this had been used up, the workmen reached the same moraine mass which occurs below, along the carriage-road. Some of the earth was sandy, and went into the composition of the mortar used on the walls. There was scarcely any ledge requiring removal. I examined such of the stones as remained in the cellar as well as possible with a dim lantern, and found everything in agreement with the character of the materials seen two hundred and fifty feet lower along the carriage-road. The stones assumed the ordinary glaciated shapes, but I did not discover any material foreign to the mountain. One of the quartz fragments seemed to show traces of smoothing or incipient striation.

Next, I examined the excavations made for the road between the house and stables, and obtained several small boulders, four or five inches long, corresponding in mineral structure with the ledges in Randolph and Jefferson, twelve or fifteen miles away. The general color of the rock is so like that of the mountain that one would not perceive the difference between them without close inspection. The mica is arranged differently in it; the white parts are more abundant, though in fine grains, and the rock is evidently the same with the upper member of what I call the "Bethlehem gneiss" in the New Hampshire reports. The highest point at which stones of foreign origin were obtainable may be twenty or twenty-five feet below the very pinnacle of the mountain. Hence it is fair to conclude that every part has been covered by the glacial ice. The glaciated stones, composed of the same material with that of the mountain, are common all along this road to the stables, and elsewhere in excavations over the summit.

Being unexpectedly called away, I had not time to search carefully for striæ upon the ledges. Just beyond the signal station dwelling I found a flat ledge sloping a little north-westerly but precipitous on the south-east. Atmospheric agencies have marred the surface so much that no striæ are visible, even if they ever existed. I had proposed to scrutinize every harder projection of quartz with a lens, as this course sometimes reveals striation where other inspection is unavailing. Were this ledge situated near the Lake of the Clouds, where embossment is common, I should point it out unhesitatingly as an example of ice-sculpture, though much degraded by weathering. The shape agrees with that of thousands of glaciated ledges in other parts of the state. Other ledges on the mountain further north resemble this one. Inasmuch as the transportation of materials is clearly proved by the presence of the Jefferson rock upon the summit a few rods away, it will not be unreasonable to believe that this apparent embossment is real. The altitude of the ledge is the same with that of the site of the travelled stones.

The disposition of the large blocks upon the summit is noteworthy. Several acres of surface are covered by them far away from visible ledges. As you approach a ledge, it is easy to see what fragments have been separated by frost action, as the projections match the indentations; and a very few feet of distance represent the extreme amount of removal, save on a steep slope. Since the surface covered by the large angular blocks is quite extensive and comparatively level, it is fair to conclude that the transportation has been affected by the glacier and not by frost. The latter agency, however, has very industriously operated upon both ledges and boulders in post-glacial times, so that the shattered ledges, their fragments, and the fractured boulders form a continuous field of angular débris over the whole upper cone of the mountain.

From these facts, the following conclusions seem legitimate:

1. The glacial ice completely covered and passed over the summit of Mt. Washington in a south-easterly direction.

2. It brought along a large amount of moraine rubbish and glaciated stones, which were disposed in various hollows and convenient locations about the mountain, in the same way that the ground moraine is distributed in the lowlands.

3. Subsequently an immense number of large blocks of stone, taken from the northern slope of the mountains, were transported to the summit (as well as beyond), and left overlying the finer earth débris of a previous transport.

4. Frost and gravity have been acting upon the boulders thus transported and the ledges, so that every large block has been split up into smaller ones; and this angular débris entirely conceals from view the previously formed moraine, and the summit is apparently destitute of soil.

After the announcement of this discovery, it was objected by some that these transported foreign stones might have been brought by teamsters or by the railroad. It was said to be a common custom for the men to place canvas over articles in their vehicles for protection, and to fasten down the cloth by stones. On reaching the summit, the stones would be thrown away, and perhaps the glaciated bits might be some of the fragments thus transported. The boulders I found were not over two pounds in weight. These would hardly be sufficient to hold canvas down in a wagon in the teeth of the formidable winds often blowing at the summit. Still, I thought it best to search further in localities not reached by débris. About fifty feet below the summit, midway between the railway and carriage-road, I soon found a rounded block of light gray Bethlehem gneiss weighing ninety-one pounds, evidently the rock that is common about Jefferson, but very different from the material composing the mountain. It lay beneath other fragments of stone, partly embedded in earth, and showed patches of the common yellow lichen of the summit growing upon it, older than the date of the building of either road. I therefore concluded that no human agency ever brought this heavy stone and planted lichens upon it; nor is it probable the ones first discovered reached the summit except as borne by ice. Hence the proof of the presence of glaciated foreign transported boulders upon the summit of Mt. Washington is indisputable. These consist of two different members of the Bethlehem group, together with a trap rock of unknown origin. The larger boulder is preserved in the state museum at Hanover.

Further examination of the smoothed ledge west of the signal office confirms the impression of ice-action mentioned above. Faint markings indicate the course of S. 43° E., while the smoothing is very obvious to the touch, and is best seen where some of the ledge had been recently exposed, and especially upon a finer-grained stratum than usually occurs. The weather roughens every exposed surface in a very short time, so that this smoothness cannot be expected to continue a great while. This example was shown to Mr. E. Lewis, Jr., of Brooklyn, N. Y., a geologist familiar with glacial phenomena, who agreed with me as to its nature and origin. The course of the striæ and dispersion of the boulders both indicate the movement of the ice to have been from the north-west to the south-east, a direction in unison with corresponding phenomena upon the neighboring summits. It is therefore clear that the ice moved south-easterly from the St. Lawrence valley towards and over the highest ranges and peaks of New England (6,291 feet), in the direction of the Atlantic ocean. Our discoveries may increase the difficulty of explaining glacial phenomena in New Hampshire; but it is better to meet the truth, though formidable, than to adopt errors. All speculations, claiming that Mt. Washington rose above the ice, or constituted the central peak from which local glaciers radiated in the height of the glacial period, are false. It will be shown soon, however, that local glaciers occupied the flanks of the White Mountains during the decline of the ice period. This does not interfere with the fact of the earlier mightier movements.

Directions West of South.

A few examples of a current west of south have been observed. The first of importance occurs upon the east side of Mt. Washington, passing from Gorham up the Peabody valley to the Glen house, thence to the height of land and down the Ellis valley past Jackson. The course is S. 15° W. near the Glen house; S. 3° W., half a mile south; and perhaps a little east of south into Jackson. The valley must have been filled certainly as high as the Half-way house on the carriage-road, where the course is S. 8° W. Perhaps the most natural way to explain this case is, to say that ice from the north entered the mouth of the valley at Gorham, and, being powerfully urged onwards, followed up the Peabody river, because that lay in the direction of least resistance. Whether this action was coeval with the motion on Mt. Washington, is doubtful; most likely the intensity of that force had somewhat abated before this culminated. The valley is on the lee side of the mountains, and might possibly have been moving at the same time with that on the summits without inteference. Dr. Packard has cited this valley movement as an illustration of a local glacier passing northerly down the Peabody river to join the Androscoggin.* In this he is followed by Vose.† The latter thus states the case:

> The Peabody river rises upon the eastern slopes of Madison, Adams, Jefferson, Clay, and Washington, and upon the western slopes of the opposite range of the Carter mountains,—the Imp and Mt. Moriah, and flows about N. N. E. to Gorham, where it joins the Androscoggin. The surface geology of this valley is exceedingly interesting. It has been carefully studied by Dr. Packard, and, from the arrangement of its terraces and the other forms of the unconsolidated material, he concluded that a large glacier once occupied this valley, extending as far down as to Gorham. His conclusion is somewhat confirmed by the following facts: About 150 yards north of the Glen house, just south of a large boulder upon the west side of the road, the surface has been cut open, and has exposed a portion of a ledge, perhaps a dozen feet in length and a yard wide, on which, at right angles to the contorted lamination of the rock, faint lines, or, rather, furrows, are seen, running N. 35° E. or S. 35° W. This ledge was covered several feet deep by the material of the terrace in front of the Glen house. Just across the valley from the hotel, where the carriage-road commences to ascend, the upper part of the large exposure on the right hand is well polished and furrowed in a south-west direction. Half a mile further up the road, furrows upon the right side, close to the road, are seen running S. 40° W. or N. 40° E.; and, again, a short distance above the path leading to Tuckerman's Ravine, upon a surface somewhat inclined towards the road, may be seen lines running S. 30° W. or N. 30° E. Many more traces would doubtless be found in this neighborhood, if sought for with care, as the few recorded were noted without stepping out of the common road.

These and other examples given in the table have been carefully examined; but I am satisfied the force proceeded up instead of down the valley. If the facts about stoss and lee sides of ledges declare truth, there can be little doubt as to the south-west direction. Some of the examples given require scrutiny to decide which is the stoss and which the lee side, but all present the same appearances. Perhaps the most satisfactory cases are recently exposed by a clearing midway between the Glen house and the saw-mill, not seen by either Packard or Vose. The rounding on the north sides of the domes here is very conspicuous, while the south sides are rough and uneven, though not so much so as in the most perfect examples of stoss and lee action. At the lower end of the carriage-road the smoothing occupies a broad face of rock 200 feet long and 40 wide, with the north-east end the most worn. Two miles up this road the markings are on a vertical wall exhibiting a well defined example of the north-east force. A short distance south from the Glen house, where a tributary enters from the south-east, the greatest amount of wearing appears at the angle of the fork, and not upon its sides. All these cases show clearly that the principal force, or that making the striæ and producing the embossment, proceeded west of south, and not northerly. There may have been a later current down the valley in the decline of the period, but this did not have strength enough to score the ledges. This later current explains the origin of the immense thickness of stratified deposits near the mouth of the Peabody river, called moraines by Packard and Vose. They are relics of the ancient flood plain, produced by the glacial river after the ice had been melted, certainly as far up as the Glen house. These terraces are very conspicuous as far south as the mouth of Miss Barnes's brook, and show differences in coloration like those between the upper and lower till. Mr. Upham agrees with me in this view (see p. 141), without any conference or suggestion whatever from me.

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* *American Naturalist*, vol. i, p. 267.

† I'd, vol. ii, p. 287.

The next examples of the movement west of south occur on the west side of the Presidential range, and seem to connect with the Connecticut Valley movement. It has not been observed in Carroll, probably because of the scarcity of ledges. Observations are also wanting for Whitefield. Bethlehem abounds with them. The north-west slope of the Mt. Agassiz eminence has been powerfully struck and smoothed by it. This current passed over the summit of Mt. Agassiz, and followed some portions of its southern slope. From here southerly the current is merged with that of the Connecticut Valley movement. That seems to commence with the Passumpsic. The great westerly bend of this valley below Dalton, and the sudden fall of the land, may have prevented the ice of the upper Coös flats from descending to Barnet. Certain striæ in West Littleton, near Milliken's saw-mill, cross the Connecticut, and ascend Gardner mountain in preference to following around the lowland. Our numerous observations in Littleton, Lyman, and Monroe show that the prevailing course was a little west of south, conforming both to the longer axis of the Gardner range and the Connecticut valley. The whole area of this westerly course may be readily referred to the Connecticut Valley movement, of which more will be said beyond.

Another area, showing a course west of south, is in the Lake District. We have on the south slope of Pequawket, S. 6° W. (misprinted in the table); Madison, S. 7° and 12° W., besides S. and S. 2° E.; Brownfield, Me., S. 18° W.; Eaton, S. 3° E. This area is essentially a valley sloping southerly; but there are no indications of this direction in its continuation in Ossipee or Wakefield, nor in the broad opening to the south-west between the Chocorua and Ossipee mountains. The striæ point south-east in both these localities. Hence the reason for this course in the Lake District is not obvious. Probably extensive explorations in Maine will be required for the solution of this problem.

Those nearer the coast might be referred possibly to iceberg agency, or to some connection with the ocean. They are at Cape Elizabeth, close to salt water, S. 8° W.; at Limington, Me., S. 33° W., numerous and well marked for half a mile's distance, seen in crossing a hill; at Danville Junction, Me., a little west of south; and at Bow lake in Strafford, S. 31° and 58° W. The usual direction in this neighborhood is fairly at right angles with these. Is it possible that these are scanty relics of a once abundant south-west glaciation? Some of the lenticular hills, about to be described, are arranged in a line suggestive of a connection with a south-westerly current, much more extensive than is indicated by the striæ. The course of S. 59° W. in Sutton cannot easily be classed with either of the foregoing.

We cannot properly appreciate the importance of this movement without reference to other observed examples obtained outside of New Hampshire. In Maine they are S. 8° W. at Saco, and about the same at Rockport. In Vermont they are S. 50° W. at Halfax centre; S. 28° W.

at Marlborough. In Massachusetts they are S. 20° W. on the summit of Mt. Pocumtuc, 1,888 feet above the sea; S. 50° W. at Granville, 1,240 feet. In Connecticut, according to Prof. Dana, there are striæ proceeding S. 30° W. on Mt. Carmel, and S. 33° W. half a mile west of Allingtown on the Milford turnpike, a few miles west of New Haven.

South-East Direction.

The south-east course is well-nigh universal. All over Coös county and about the White Mountains there is scarcely any variation from it upon the high ground. It is the most common in the lower part of Carroll, Strafford, east part of Merrimack, east part of Rockingham, and on the isolated mountains of the Monadnock type everywhere. In Belknap and the west part of Rockingham the course averages a little less easterly than south-east. The Winnipiseogee Lake neighborhood is much the same. In all the regions showing a west of south course are many cases of this south-east grooving. About Madison we have noted S. 22° E. The Strafford hills indicate S. 35°–78° E. In the Connecticut valley numerous examples are given. We find in Lancaster, S. 23° E.; at Haverhill, S. 21° E.; at Newbury, Vt., S. 23° E.; at East Lisbon, S. 28° E.; in Bethlehem, S. 28° E.; in Piermont, S. 42° E.; in Lyme, as high as S. 31° E.; in Hanover, S. 38° and 51° E.; in Lebanon, S. 51° E.; in Enfield, S. 16°–61° E., but most commonly about S. 22° E. A full description has been given already of the remarkable eastings in Claremont. At Unity the course S. 51° E. occurs, and S. 61° E. at Hinsdale. Along the Connecticut-Merrimack water-shed the direction is commonly between S. 20° and 40° E. These south-east courses in this valley must not be confounded with those conforming to the direction of its contour, about to be mentioned.

The universality of a south-east course among the striæ shows that this was the most common direction taken by the ice in its southerly movement. All other directions are exceptional, and probably produced subsequently by an action differently directed.

Valley Movements.

To this class I refer all those examples of striation where the ice seems to have followed the topographical contour of the country, including all the local glaciers. In most glaciated countries it has been found practicable to refer all the ice-action to this class of movement; but in New Hampshire the most characteristic phenomena have resulted from a motion made in total disregard of all topographical obstacles or allurements. On the supposition that ice moves up hill only when forced by a flow starting from an eminence higher than what is being surmounted, we must believe that, to the north of the St. Lawrence valley, the land was elevated several thousand feet higher than at present. This is Prof. Dana's view. It must be adopted, unless we can show that reasons exist why the ice can move up hills higher than the source of the flow.

The most important valley movements in New Hampshire are those in the Connecticut, Merrimack, Blackwater, Baker's river and Winnipiseogee lake, the Androscoggin, Saco, and others. I will describe each in turn.

Connecticut Glacier. None are better marked than this. It starts with the Passumpsic and the Lower Ammonoosuc valleys, and, below Haverhill, occupies commonly the width of two townships, one on each side of the river, into Massachusetts. It continues across Massachusetts, with a course a little west of south, as has been described in my father's publications. On both sides the course is east of south. It follows, therefore, that this movement must have been entirely independent of all others. As it conforms to the valley, while here and there a few remnants of the south-east course remain as relics, its existence was probably subsequent to the other, and in the decline of the period. By observing the present heights of the striated ledges, we can determine the minimum thickness of this glacier. It covered Mt. Agassiz in Bethlehem, the higher parts of Lisbon and Landaff, the Gardner mountains, or over 2,000 feet of altitude. Lower down the valley it attained the height of 1,100 feet at the Haverhill soapstone ledge; 1,400 feet near Tarlton pond in Piermont and Warren; 1,500 feet upon Sunday mountain in Orford; 1,600 feet in the south-east part of Hanover; and it may have reached the summit of Mt. Ascutney, or over 3,000 feet. South of this mountain, none of the recorded observations exceed 1,000 feet,—most fall below it. On Bear hill, Hinsdale, they stand at 700 feet. In Massachusetts we found one example, at New Salem, on the east rim of the valley, certainly as much as 1,200 feet high. Similar marks have been found at the same height over the Holyoke range, or upon Mt. Tom. Allowing for the elevation of the river bed, this glacier must have exceeded 1500 feet in thickness in the Ammonoosuc valley, and probably 2500 feet at Windsor. From Prof. Dana's paper,* it is obvious that the ice continued a little west of south to New Haven, Conn., thus following the depression of the valley to Long Island sound. The breadth of the area showing striæ conforming to the river's course is greater in Massachusetts and Connecticut than in New Hampshire and Vermont, as might be expected where the valley itself is broader. So far as can be conjectured, the heights are less in the more southern states; and it is bounded by the east of south course on both sides as sharply as further north.

It would be repeating observations uselessly to print again the numerous statements about the course of the striæ along this valley given in our table. That may be consulted to understand how fully the river towns abound with groovings following the general course of the valley.

Prof. Dana argues that the Connecticut valley ice moved towards the sea at the same time that the great ice movement was in progress southeasterly upon both sides, and explains it as the necessary result of a natural law. "It moves just as thick pitch poured over a sloping surface, in which there are a few large groovings, would move, the mass following the general surface, and the portions in the grooves nearly or quite the course of the grooves. The thickness of the ice that followed the course of the valley was at least 2,000 feet." Three considerations are presented in favor of this view:—first, in Massachusetts and Connecticut only the course with the valley has been observed; second, if the glacier were local, 2,000 or 3,000 feet thick, the southerly scratches ought to be found further west than they now are; third, there is more easting in the course north of Massachusetts, as if produced by some part of the general movement. I think it much better to believe the Connecticut Valley movement was confined exactly to the limits where its evidences are found, and to say that the south-east courses found here and there within it are the relics of an earlier and grander glaciation. In fact, when different parts of the same ledge, as in Hinsdale, show the courses S. 10° E. and S. 60° E., no amount of argument can convince one that the ice moved in both these directions at the same time. It is impossible.

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* *Am. Jour. Science*, iii, vol. 2, p. 233.

The phenomena agree best with the theory that the south-east course originally covered both the valley and the adjacent borders for scores of miles, but that, after the ice ceased to be furnished abundantly from the St. Lawrence, the residue followed its natural way down the several river depressions to the sea, and, being of considerable thickness, was able to leave abundant evidences of its passage.

Prof. J. D. Dana was the first to insist upon the existence of a Connecticut glacier separate from the general mass of drift. My father was the first of American geologists to point out the fact in any publication of the existence of local glaciers radiating from high ridges.[*] He was led to this conclusion from a comparison of the ancient glacial drift in Wales and Switzerland with the drift generally, and with the local examples seen by him in western Massachusetts and Vermont. As the common phenomena of the drift seemed to him best explicable upon the iceberg theory, his ready recognition of the real glacial markings in the Westfield and Deerfield River valleys shows how ready he was to accept truth, even against his judgment of the proper interpretation of the phenomena of nature. His suggestion of a movement down the Connecticut valley is not to be regarded as a claim that he understood the whole depression to be scored like the few examples he had seen.[†] The fact established clearly by him was, that the Hoosac and Green Mountains supported the *mer de glace* in the last part of the ice period, from which local glaciers flowed down, both towards the Connecticut on the east, and to the Champlain valley on the west. We can now extend this deduction eastwardly, and say that there was a Connecticut Valley glacier in the latter part of the ice period, with branches both from the west and the east.

The branch glaciers on the west that have been described are these: Upon Westfield river, with its tributaries, especially Little river; Deerfield river, both in Massachusetts and Vermont; West river, joining the

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[*] *Report Geology of Massachusetts*, 1853. *Smithsonian Contributions*, vol. ix.

[†] The following is the passage referred to (*Smithsonian Contributions*, vol. ix, p. 136): On examination, I did find, on the west side of the Connecticut valley, that what I called drift striæ, instead of running north and south, as they usually do, turn southerly south of South Hampton as much, in some places, as S. 65° W. I suspected at first, either that these markings were produced by the [Westfield] glacier, after it reached the Connecticut valley, or that the supposed glacier scratches were the result of drift agency operating up hill. But when I found that the stoss of the glacier striæ was the west side, and that of the drift striæ was the north-east, both these suppositions were shown to be untenable; and I accounted for the south-west direction of the drift striæ by the expansion to the right of the Connecticut valley south of South Hampton. I think this the right interpretation of the facts, but I could wish to give them further examination.

Connecticut just above Brattleborough; Saxton's river; Black river in Ludlow and Cavendish; Otta Quechee river; White river. Those farther north have not been particularly explored. On the east side, the branches of this glacier are not well marked. This may be explained partly from lack of attention directed to their discovery, but chiefly because the east side of the basin is very narrow. There is not sufficient room for the glaciers to form, and to make much sign of their existence. In Massachusetts, Miller's and the tributaries of the Chicopee river might furnish some indications of the former presence of the ice. In New Hampshire, the Ashuelot is the first valley where we could search for these relics. They may be expected in Winchester, where the river changes its course to pass between hills, and in the towns of Surry and Gilsum. It will be singular if these localities do not afford striæ or other indications of the tributary ice-sheets. We have no observations for Cold river; and all that has been noted in the Sugar River valley indicates the passage of the ice up instead of down the stream. The marks of the older south-east current were so pronounced that any action of a force in the opposite direction might be unnoticed. The Mascomy valley is rather short; and ledges between Enfield and Hartford, Vt., are rare. There is a moraine-like accumulation of till about a quarter of a mile below the outlet of the lake, whose origin may be explained either by supposing it to be the frontal rubbish of a local glacier, or the filling up of the valley by the south-east current from Hayes hill. The existence of the projecting hill is very marked; and it is spoken of by the residents of East Lebanon as a former barrier to the progress of the water, so that the lake must once have had a much greater extension, leaving its shore marks forty or fifty feet above the present level of the water in beaches of sand. Excavations in this barrier show both the lower and upper till with great distinctness. Next come Mink brook, Hanover; Great brook, Lyme; Jacob's brook, Orford; Bean's and Eastman's brooks, Piermont,—none of which afford marked glacial features, that is, we have not noted any. On the north branch of Jacob's brook, between S. H. Sargent's and the water, are many large blocks of Bethlehem gneiss, the rock which is in place a mile higher up, and not at the place of crossing. I did not follow down the stream to search further for these boulders. But the evidence is clear of the transportation of rocks down the stream in a westerly direction; and this may indicate what sort of phenomena should be looked for, in the other westerly descending valleys mentioned, to satisfy us of the existence of tributary glaciers. No pains have been taken to observe this class of facts. Oliverian brook in Haverhill may be expected to show some signs of a local glacier descending the west flank of Moosilauke. On page 30, considerations are presented to show that unusually abundant gravel and sand deposits in Haverhill must have been derived from such a source as this local glacier would be. We have also a barrier-like ridge of till lying across the Oliverian valley suggestive of a former terminal moraine. There are many boulders of Bethlehem and porphyritic gneiss in the Oliverian valley, seemingly of eastern origin. If not from the Moosilauke pile, they must have been brought down by the main Connecticut Valley ice. The numerous marks between Haverhill and Carroll may be regarded as made by one branch of the Connecticut glacier. These are very abundant, and satisfactorily illustrate the local movement. Those down the Passumpsic valley are less common and convincing.

Above the Ammonoosuc district the Connecticut Valley movement seems to have been interrupted in consequence of the presence of the Gardner Mountain barrier. The markings in this part of the valley do not conform to the topography, and must therefore be regarded as made by the older movement. The map (Pl. II) illustrates the nature of the ground over this space. Above Lancaster there are well marked signs of a local glacier, probably the last movement in the region, separate from and later than that just described. Its existence is manifested by moraines and not by striæ, and may be classed with the Bethlehem glacier, to be described presently in the words of the late Prof. Agassiz.

Midway between Stratford Hollow and North Stratford is a pile of granite boulders so conspicuous as to arrest the attention of the most careless. They occupy several acres of ground, and seem to form a terminal moraine. It is represented in Fig. 53. The exact location is indicated by the word Moraine on Pl. I; and a section crossing the valley is shown in Fig. 2. Mr. Clough's stereoscopic view of the same is entitled "New Hampshire Cow Pasture." The name indicates the use to which the field is put, while the abundance of boulders seems to have discouraged the owner from attempting to make a stone wall of the material. A dozen walls would so slightly exhaust the supply that none of the boulders would be missed. The largest boulder represented weighs about 1,300 tons. On looking across the valley, similar boulders, but less abundant, can be seen on the Vermont side. I suppose they extend beneath the intervening meadow the whole distance, and therefore present us with an admirable example of a terminal or frontal moraine. The material corresponds closely with the granite quarried a few miles up the Nulhegan river by the side of the Grand Trunk Railroad. The ice there seems to have descended the Nulhegan river before joining the frozen stream of the Upper Connecticut. Pl. I shows a projection of glacial drift into the valley, at Horseshoe pond, in Northumberland. This promontory is suggestive of other terminal moraines farther to the south. I do not recall their nature, so as to say definitely whether the resemblance is only accidental. It might be added, that the drift hills on Israel's river approach each other closely, just above Lancaster village, in the manner of a frontal moraine.

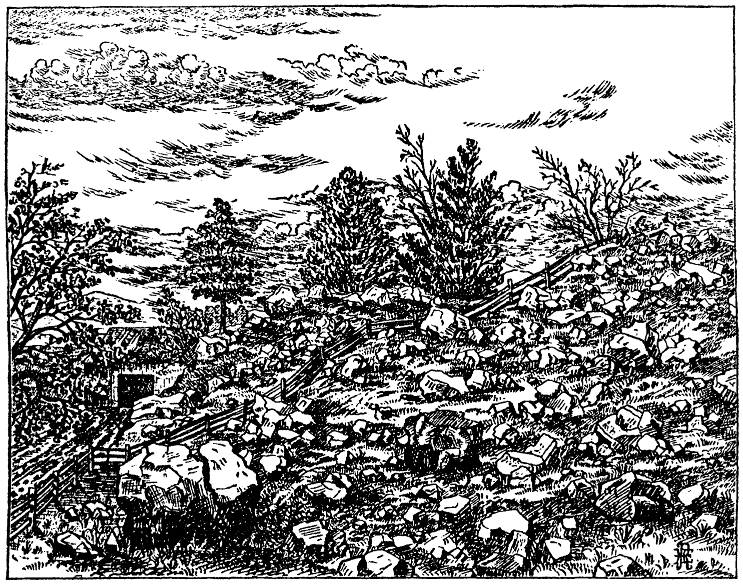

Fig. 53. MORAINE IN STRATFORD.

The Merrimack Movement. The limits of this particular ice mass would be naturally the east and west water-sheds, while the northern boundary does not extend beyond New Hampton on the main stream, passing instead to Newfound lake. The movement north of New Hampton belongs to another area quite distinct. It is thus like the Connecticut glaciers, divided by a barrier above Monroe. As thus limited, the Merrimack glacier is with difficulty separated from the general southeasterly movement. The country is almost flat below Concord, so that there is little opportunity for a local glacier to exist for want of inclination; and the western sloping valleys on the east side rarely show any marks pointing westerly. From Winnipiseogee lake to Franklin the descent is sufficiently great to induce motion, 225 feet in fifteen miles, but the ledges are covered, and no topographical feature suggests glaciation. Any special striation or embossment in the lower part of the Suncook and Soucook rivers would be concealed by the immense piles of alluvium of later origin. The upper Souhegan valleys are better adapted to show these evidences; and no situation could be better than that of the upper Contoocook for exhibiting traces of the glacial action distinct from that of the general drift. Warner river valley is much like the Souhegan. Three of the more northern tributaries of the Merrimack show good evidences of the valley movement,—Smith's, Blackwater, and the Pemigewasset rivers. I will describe these first.

Smith's River. This stream rises at Orange summit, follows the Northern railroad through Grafton and Danbury, and thence turns easterly between Alexandria and Hill. The course of the valley usually corresponds with that of the general movement, but the phenomena of embossment are like those of local glaciers. In the Orange summit notch, the course is S. 36° E., a few more degrees easterly than is common in Canaan and the north part of Orange. It is the same at the north end of Tewkesbury pond, but 5° less at the outlet. The rock for several miles about is admirably adapted to exhibit striation and embossment, and the phenomena at the outlet of the pond where the railroad passes can hardly be excelled for perfection in any part of the state. Any one familiar with glacial phenomena would instantly recognize them while passing in a train. At the mica quarries on the west side of Grafton valley, the course is about the same; also, at a school-house between the two Grafton stations. We should expect somewhat more easting at this point, as the course of the valley has commenced to change. Two tributary valleys from the north, Mill and Whittier brooks, may show striation coursing more southerly; but these, and all the rest of the Smith's brook region, have not been specially examined with the object of noting the glaciation. The lower part of Smith's river changes its course so much that if a mass of ice followed it, the variation in the direction of the striæ would be very observable. Between Alexandria and Hill there has been considerable excavation since the ice period, so that the markings may be looked for away from the stream. We have good reason to expect to find evidence of local action all along Smith's river, provided the ledges are not too much covered up.

Blackwater Valley. The map of local glaciers in Volume I represents the movement of the ice as continuous from Grafton and Danbury along the railroad, to connect with that in Andover along the Blackwater. I have separated them now, because it seems more natural for the ice to flow down Smith's river to join the Pemigewasset, than to cross the Danbury water-shed, where the necessary rise is not far from a hundred feet. The course in the south part of Grafton, on the highlands, is such that the continental sheet points directly to Andover, or to the valley between Mts. Ragged and Kearsarge. It is not therefore certain that the ice going down the Blackwater, whose marks remain, should be classed with the later movements. But it is certain that the course was modified by the valley, so that it belongs to the category of those motions whose course did not proceed in defiance of elevations and depressions of the surface. Several ledges at Potter Place and Andover show that the course was much more easterly than the very east directions upon Kearsarge and Ragged [see page 200]. It has 20° more easting than on Kearsarge, and 40° more than upon Ragged. This course would naturally turn at Andover Centre, and proceed southerly through Salisbury, if it continues to conform to the valley, and not climb the hill at East Andover like the railroad. Such facts as are reported confirm this view. The East Andover ridge is occupied by drift, perhaps lenticular moraines; and the striæ in West Franklin run S. 32° E., and therefore belong to a different movement. The top of a hill west of the Blackwater, on the south town line, shows the course S. 38° E., and on its south slope are striæ running down hill towards Salisbury. And in this last named town the courses are S. 12°, 15°, and 22° E., the greatest easting being in the valley on Bean's hill, near the south boundary line. The courses in Webster would not vary essentially from those in Salisbury.

The Pemigewasset below Ashland. Local glaciation probably reaches from the mouth of this stream at Franklin all the way to Newfound lake and up Cockermouth brook in Hebron and Groton. At the outlet of Webster lake the course is S. 32° E., which may represent the normal direction to the west of the Pemigewasset. North of Franklin village the direction is S. 27° E. This continues uniform for three miles; and the grooves and embossment are remarkably well developed near J. W. Simonds's. At this point there is a conspicuous bend in the course of the valley; and the striæ are observed to change their direction to conform with the topography. At S. Pike's, a mile beyond Simonds's, the striæ point S. 42° E. From here to Hill the valley broadens, and the ledges are covered by sand. At the east side of the river, in the north-east edge of Franklin, the course is S. 22° E. down the valley, and the accompanying embossments are admirable. This locality is opposite to the first named examples below the prominent bend in the river.

On the Sanbornton side of the valley, between Hill and Bristol, there are ledges which have their stoss sides marked from the north, and they probably present other illustrations of the local action. Our table contains several observations of south-east striæ down the valley of Cockermouth brook in Groton. The east side of the lake shows other striæ, however, pointing up hill, and therefore having no connection with the local glacier.

There are examples of a local sliding in New Hampton and Bridgewater. These are all connected with the Pemigewasset movement, and are mentioned in the tabular list.

The Lower Merrimack. Several points may be made about the lower Merrimack movement. The general direction of the valley is S. 15° E., so that striæ varying ten degrees from this on either side may be regarded as belonging to this special glacier. From Franklin to Massachusetts we have, in order, S. 15°–27° E.; Canterbury, 15°–40°; Boscawen, 17°–27°; Concord, 9°–11°–21°; Hooksett, 16°–26°; Manchester, 15°–26°; Londonderry, 11°–21°; Souhegan village, 16°; Nashua, 11°; and in Hudson an interesting case of intersection, S. 3° x 21° x 36° E. On the east rim of the basin are higher figures. Belmont, 32°–42°; Gilmanton, 32°–52°; Loudon, 40°; Pittsfield, 42°; Deerfield, 40°; Northwood, 32°–37°; east part of Hooksett, 41°; ridge east of Manchester (quarries), 40°; Candia, 21°–41°; Londonderry, 41°. It would seem as if these observations might be interpreted as indicating a difference between the direction of the forces down the valley and over the eastern rim. There are a few strongly marked south-east courses on the west rim, as through Washington and Springfield, that are between 20° and 30°. Hence there is not that definiteness of demarcation between the rims and the valley courses that we found in the Connecticut. The three courses in Hudson may perhaps be regarded as typical of as many different movements. The unusual direction of S. 72° E. in Deerfield, on the north side of Mt. Pawtuckaway, may have been due to the presence of the mountain mass.

There is one example of striæ sliding N. 40° W. on the east side of the valley. It is at the Amoskeag granite quarry in Manchester. Its existence would not be known save for the removal of the earth for quarrying. Who knows how many more such cases may exist under these loose materials, sufficient to make sure the presence of the glacier in the Merrimack valley!

In the Contoocook valley we find no evidence from striæ to suggest the northward motion of the ice. Unusual accumulations of till at Hillsborough Bridge and in the west edge of Henniker are suggestive of terminal moraines pushed forward by such a movement. The striæ in Antrim follow the course of the valley, but may have gone southerly. The North Branch valley, in the same town, is deep and narrow, and hence well fitted for the passage of a glacier. We find marks indicating that it was crossed by the main ice-sheet without regard to the depression.

Our final conclusion, from all the facts, must be, that the Merrimack movement was largely a topographical modification of the course of the main ice-sheet. As occasional remnants of the genuine south-east current occur, it may be proper to say that the modification would naturally take place in the interval of time between the predominance of the south-east current and the local glaciers. And in the latter period the Merrimack ice became still more restricted, and feebly imitated the local action elsewhere.

Baker's River and Winnipiseogee Movement. This is an interesting example of a movement seemingly both local and hardly separable from the action of the continental sheet. It starts with a south valley in Benton, curves to the east with Baker's River valley in Rumney, extends nearly due east over Squam lake and Sandwich, and then enters the valley of Winnipiseogee lake, merging into the normal south-east course after leaving this hydrographic basin. Allusion has been already made to the latter part of its course (p. 121 *et seq.*). The movement down the upper Pemigewasset may be regarded as a branch of this.

On the summit of Moosilauke the striæ run S. 22° E., a course less easterly than is common over the high mountains of the state. This corresponds with the direction through Warren and Wentworth, save a few local tributaries in Warren mentioned in the table. The easting seems greater than the proper course of the valley; but a correspondence was noted between the direction of the striæ and of the depression when the observation was recorded. The numerous observations in Rumney indicate a gradual bending of the scratches in complete agreement with the change in the course of the valley. On the south side, the south-east course does not reach the top of the rim, as the directions in Groton on the ridge between Baker's river and Cockermouth brook are S. 22° and 32° E. The glacier was certainly 500 feet thick, and probably not much more at this point. In the west part of Plymouth and the south-east corner of Rumney are remarkably fine examples of striation and embossment of the ledges. I hardly think a finer place could be found for a photographic representation of these phenomena than of the east base of Hawks mountain in Rumney. A spur of the hill projects into the valley, which was struck powerfully by the ice as it descended, beautifully embossing the schists and scoring the domes with striæ. One ledge has numerous large blocks of stone on top, some measuring as much as 20 feet long, 10 wide, and 8 high. Further west the mural striated surfaces are common, as between A. Kelley's and J. Davis's houses. On the north side of the valley two elevated ranges come close to the river,—Rattlesnake and Stinson mountains,—which are precipitous for two hundred feet. On these steep sides striæ are often visible, though much of the rock containing them has fallen to the base of the hill. Wolf hill in Plymouth, a solitary bunch of granite in the midst of a low country, has been passed over by this glacier as if it were of no consequence.

The Pemigewasset valley turns to the south below Plymouth; but the striæ continue on in the direction observed in Rumney, just as if the ice could not stop after it began to slide. The smallest easting in Holderness is S. 37° E., on top of Mt. Prospect; the ridge of Squam mountain shows S. 62° E.; and there are others equally pronounced. Sandwich, however, shows the greatest amount of easting. At several places it travelled a little north of east, and the east course is frequent. The movement did not continue further east into Tamworth on the north side of the Ossipee mountains, since the marks there are quite southerly, though Chatham hill shows the course S. 42° E. The mass seems rather to have gone south-easterly to the lake through Moultonborough, and over Red hill, S. 62° E. On reaching Winnipiseogee lake the striæ on the east side average a more easterly course than on the west side in the towns of Meredith, Gilford, and Alton. The occurrence of the Moose mountains directly in the path of the Winnipiseogee ice suggests whether the course was not changed on account of this obstacle in its way. It is a fact, that the course on the summit of these mountains is that of the longer axis of the lake, while there is a much greater easting to the north-east. The striæ at Tuftonborough Corner run N. 68° E., as if crowded closely upon the flank of the Ossipee mountains. Nearly all the observations in Tuftonborough, Wolfeborough, Brookfield, and Wakefield run between south-east and east. Mr. W. Upham explains this condition of things, by supposing the ice of the Ossipee basin melted earlier than that over Winnipiseogee, and hence the ice from the latter area moved towards the vacancy left on the east side. If most of the ice were forced to pass out between Ossipee and Moose mountains, a part of it might emerge through Alton. The striæ there have a much less easting than on the other side of Moose.

Thus it would appear that the topography of the country between Warren and Wakefield, along the valley of Baker's river and Winnipiseogee lake, determined somewhat the direction of the motion of the ice, whether it be regarded as a part of the continental sheet or a local movement.

Upper Pemigewasset Movement. The observations of the striæ in the upper Pemigewasset valley are grouped together in the table (p. 185). The valley runs southerly, and the striæ mostly conform to it; at the very entrance, high up, we have the course S. 8° W., above the Eagle lakes on Mt. Lafayette. On the summit of Bald mountain, in the Franconia Notch, the course is S. 2° E., with a large boulder of Bethlehem gneiss on its summit. The same force went over Mt. Profile, leaving many boulders of the same kind. It appears from these circumstances that a large body of ice entered the valley from above, which must have been a portion of the larger and older sheet. This and the later local masses scored the vertical east side of Mt. Pemigewasset, with the course S. 12° E., working southerly. Other examples occur through Lincoln and Woodstock, following the valley. Were the forests cleared upon both sides of the stream, many other interesting examples would be found. At North Woodstock, the hills upon the west side display a magnificent embossment on a large scale, as worthy of photographic reproduction as those in Rumney. There seems to be more easting in lower Woodstock and Thornton than is needful to conform to the valley. This may be explained partly by the fact of local turns in the course, not obvious, except on the ground. On the rim of the valley to the south-east is the course S. 70° E., which may have influenced somewhat the direction of the ice lower down, yet is sufficiently different to satisfy us that the marks in the valley were not produced by the same movement. Through Campton the scratches essentially follow the valley. A single case is reported from Mad river, high up, of a descent N. 32° W., or down one of its tributaries. This will be an example of the local movement, or possibly the result of a recent slide, described in Volume I. Below Campton, the Pemigewasset glacier joined the ice movement down Baker's river, and went with that over to Lake Winnipiseogee.

Androscoggin Movement. Should a glacier start from the Rangely lakes and follow down the whole Androscoggin river, the course would be to the south-west, then south, and then a turn to the east as far as Bethel, in Maine. We have evidence of a strong south-east current over Rangely lake, and in Upton on the east side of Umbagog lake,—a movement not of a local character. Down the Magalloway river, close by the College Grant, there was a well defined valley movement, S. 4° E., towards Umbagog lake. There is a pretty lateral moraine of granite blocks at the uppermost landing of the steamboat in Wentworth's Location, resting upon Huronian schists. The rocks for several miles up the Magalloway are finely embossed. The numerous striæ in Errol, S. 73° E., have no connection with the Androscoggin, and we have no further observations from this valley till we reach Gorham. The rocks here are much weathered, but have the aspect of ledges struck from above, with a few south-east striæ. According to Vose, the striæ upon the top of Mt. Hayes, directly opposite the opening of the Peabody valley, run S. 40° E., or nearly at right angles to the direction up the river towards the Glen house. The Androscoggin valley, with its low, broad terraces, is very different from the high sand-banks near the mouth of its Peabody tributary, suggesting the origin of the former under very unlike circumstances. The utter absence of all material transported down the Peabody at Gorham would indicate its removal by the powerful current of the Androscoggin, for certainly such deposits could not fail to have been brought, and seemingly at a later date than the existence of the Androscoggin glacial river. These facts suggest either extensive freshets in post-glacial times, or the longer continuance of the Androscoggin glacier. The valley below Gorham village, for two miles or more, consists chiefly of rubbish from the sides, moved by the rains and frost, not in the terrace form. No particular signs of glacial action are seen before reaching the middle part of Shelburne, near the most northerly course of the river. Here, at the height of 150 feet above the railroad, upon a projecting ridge, are grooves pointing down the valley, S. 88°, N. 88° E. The east side is a rough cliff, never touched by ice action. At the extreme north point of the hill, the course is S. 63° E. On this lee side of the dome are many rough granite blocks, each from five to twenty feet in length. They have been transported only a short distance, and are properly a moraine caught behind the projecting ledge. These markings are those of a well defined local glacier.

On reaching Clement's brook are other fine embossments, with striæ S. 73° E. The former have been described upon page 195. Local moraines appear upon the projecting side of these ledges. Similar embossments occur on the north side of the river, opposite Clement's brook. About a mile below Clement's brook, opposite the first house with a conspicuous tower, is a rough ledge, protecting moraine material. A similar ledge further east has the west side rounded by ice. Near the state line is an outcrop of white gneiss, scored S. 58° E., and an enormous quantity of boulders, torn off the light colored ledges, follow for a short distance. These several examples of blocks torn from the ledges, but not carried far, illustrate the beginnings of glacial transportation.

For about half a mile into Maine, in the town of Gilead, glacial marks are wanting. In the middle of the valley is a long rocky hill athwart its course, behind which moraine material is gathered. At the north foot of Mt. Ephraim are striæ S. 65° E., where the road and railroad draw close together.

Grooving is well shown here. Above Mt. Ephraim the rounding looks as if it had been produced by a mass of ice coming down Ingalls river from the north. On the east side of Wild river the rocks have been well planed and embossed by the force down the Androscoggin. No explorations have been made up this tributary to ascertain whether ice-marks from the south-west may not exist there. At Gilead station, just north of the railroad and ten miles from Bethel, are furrows upon polished quartz running S. 40° E. A mile further east, where the road bends around a mountain spur, are striæ S. 80° E. On the west side of Peaked hill, where the high land crowds closely upon the river, about 300 feet above the water, is a large, steeply inclined, magnificently polished surface, very plainly seen from the road below, a mile and a half distant, with faint lines and well defined furrows, S. 55°–60° E. The embossment and planishment show even better from the north side of the river. On this north side, by the bridge at Gilead station and at the mouth of Peabody brook, are grooves following the course of the valley, and also large rough blocks removed only a short distance. At a church, the markings occur almost at the water's edge, with the direction S. 75° E. On the precipitous south side of Tumble-down Dick are many examples of striæ on vertical surfaces; but the greatest force of the ice struck the ledges on the south side. At the base of the precipice, where floor surfaces are exposed, are grooved areas 150 feet long, thoroughly planed down the whole distance. It would be difficult to find more beautiful examples of ice-sculpture in New Hampshire. The striæ run S. 85° E. Near White brook are other striæ and bosses, with rough south-east lee sides.

At the east line of Gilead, on the north side, the striæ run S. 60° E. No further marks were seen on the north side of the river from this point to Bethel hill. Ledges are scarce, and covered by drift.

The observations mentioned above, between Peaked hill and Gilead, on the south side of the river, are taken from Prof. Vose's account of this interesting glacier.* I will quote his own words for the facts between Peaked hill and Bethel. His course was up the valley from Bethel.

> Where glacial furrows are found upon the tops of the Bethel hills, they run nearly north and south. Proceeding up the valley towards Gorham upon the south bank, at a point about two and a half miles above Bethel, before we really enter the close valley, and perhaps one hundred feet above the river, a small exposure of rock is seen directly in the common road, being about six feet square, with a long, gently sloping polished surface towards the north, and a steep and rough face towards the south. The furrows upon the smooth northern surface run north and south; and the hills, upon the summits of which the furrows run north and south, lie exactly north of this rock upon the opposite side of the river. This furrowing had evidently no connection with the Androscoggin, as the grooves point almost directly across it. Continuing up the valley just above Pleasant river, five miles above Bethel, about a quarter of a mile south of the road and perhaps two hundred feet above the river, the rocks are well polished; and, from faint lines upon masses of quartz, the direction of the ice is seen to have been S. 50° E. Six miles above Bethel, where the river, railway, and road draw closely together and sweep around the base of Peaked hill, there is a steep ledge, about twenty feet high, close to the track, which is polished and furrowed, both upon the nearly vertical face towards the river, and also upon a narrow horizontal shelf part way up on the ledge. The lines upon the horizontal shelf run S. 20° E., the vertical face standing S. 25°–30° E. It is necessary, however, to be guarded in drawing conclusions from glacial traces left upon vertical or steeply inclined surfaces, as the movement of ice, jamming through a narrow passage, may be locally disturbed, so as to give a direction to the furrows quite different from that of the general movement of the glacier. This was most likely the case at the point referred to, as the furrows on the opposite side of the hill—*i. e.*, the south side—ran S. 80° E., thus according much more nearly with the traces, both above and below this point, than the furrows upon the steep face towards the river do. The ice would seem to have passed around both sides of this hill; and we can readily conceive that this might be, since the depression in the rear, south of the elevation, is quite low. Indeed, in the fine view from Sunset Rock in Bethel, Peaked hill seems to rise in a very isolated manner from the middle of the valley, which makes it a very prominent feature in that magnificent picture.

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* *American Naturalist,* vol. ii, p. 284.

There are no indications of the passage of this glacier below Bethel, so far as I had time to search for them. I did not follow down the Androscoggin on the south side, and the north side only to Bear river, though I crossed it at Rumford Point. I found evidences of local action down Bear river, in Grafton and Newry, and upon Ellis river in Andover and Rumford, as well marked as those along the Blackwater in Andover, N. H. On the east town line of Bethel, the striæ run S. 4° E., and S. 24° E. On Paradise hill, south of the village, the course is S. 23° E. These all correspond to the common course of the drift in this part of the state.

Saco Valley. A few points of interest manifest themselves through the valley of the White Mountain Notch, which may be regarded as a local movement. The mountain east, Webster, shows the course S. 30°–37° E. On the west, Tom, S. 57° E., Field, S. 50° E., Willey, S. 42° E., corresponding well with the usual south-east course on the highest summits. Mt. Willard, which is really the head of the valley, shows distinct striæ, more abundant on the slate towards Field, running S. 23° E. In the very Notch, by the railroad, the course is S. 20° E. Under the Butterwort flume, close by the railroad, at a small house, are glacial lines on a mural surface running with the valley; and on the south side of Mt. Willard the course S. 15° E. was measured. On the railroad, by the Willey brook, the striæ may be seen from the train on both sides, and is thought to be southerly, as it certainly occurs parallel to the valley. Other markings down the valley directed more easterly, occur upon the north side of Frankenstein cliff. Below Bemis a mural surface shows similar scratches over a limited area. No other markings have been seen. Mt. Washington river shows an immense cliff of rudely stratified material near its mouth, comparable with the similar deposit on Peabody river produced by the melting of a local glacier. The immense amount of boulders and coarse moraine material just below Sawyer's Rock suggests detritus brought down by a local glacier. The tributary Duck Pond stream, west of Bemis, shows striæ upon a mural surface, pointing S. 18° E., which may have been connected with the Saco glacier. The nature of the rocks, readily disintegrating, and their obscurement by débris and forests, render it difficult to accumulate many facts about drift phenomena in it; but enough has been seen to indicate the probability of the existence in it of an ancient local glacier.

The Latest Glaciers.

Having now described the various phases of glacial motion in the state, referring all our observations of direction to their various classes, it may be proper to introduce a related topic, upon which much might be offered. I will content myself with the briefest mention possible.

The examination of various isolated hills in the south part of the state indicates that, as the closing up of glacial action, there has probably been a sliding on all sides from the summit, not sufficient to score ledges, but enough to push boulders to the base. It is common to find a dome-shaped hill, of not necessarily large dimensions, nearly encircled by a ring of boulders. The explanation of their presence, as suggested by a friend, is, that the ice moved from the summit down the various sides precisely like the radiation of local glaciers from lofty mountain ranges. The materials transported are what have once been acted upon by the ordinary glacial agency. Attention has not been called to this reärrangement by other authors, as there is nothing striking about it to suggest anything different from accumulations brought in the ordinary way. This action is akin to that of the local glacier, and where the hills are large would be classed with them.

I had commenced a careful study of this class of hills, when the singularity of the presence and arrangement of the lenticular moraines began to be developed, and led me to devote what time remained to that more important subject. I have therefore no well digested facts to present upon the later phenomena. I will only point out a few examples of them. To properly set forth this subject would require a thorough topographical survey, wherein elevations of ten feet would be indicated, as well as the character of the surface in all its variations of ledge, peat, meadow, forest, cleared and cultivated fields, rocky pastures, etc.

After beginning to look at our hills in the light of this suggestion, I have been surprised to discover how frequent the examples are. Such as can be readily recalled will be enumerated. One particular must first be specified, wherein these phenomena are scarcely distinguishable from others of equal importance. They are like lateral moraines. In fact, it is conceivable that the rubbish sliding down the side of a valley may fall upon the edge of a moving glacier, and be pushed along afterwards so as to constitute a true moraine. The observer will call a particular example a lateral moraine, or one derived by the later sliding, according to his prepossession. For example: in Moultonborough, between Long and Round ponds, is a long drift ridge in the middle of the valley parallel with Red hill. This may be called the local frontal moraine, sliding from the whole western slope of Red hill, or else a lateral moraine of ice from the north pushing towards Lake Winnipiseogee. I think this example, as it lies fairly in the middle of the valley, is properly a case of sliding from Red hill; but Prof. Agassiz refers to this, or one like it, in a paper cited a few pages ahead, as a lateral moraine. At the south-west end of Red hill, this same moraine changes its direction, conforming to the slope of the hill. Other illustrations are in the Wildcat valley of Jackson, which seem to be the lateral moraines of the ice filling the whole valley.

Near the town lines of Moultonborough and Tuftonborough, next Ossipee mountain, are several ridges, mostly gravelly, that seem to have been turned up by ice sliding down the elevation. By Mrs. Brian's they are large and conspicuous, with a south-east course. Further south, they begin to trend a little more southerly than is required for perfect parallelism with the mountain, and often are a mile long. Near G. Hartford's in Moultonborough is a small ridge of drift parallel with the mountain. In the south-east corner of Sandwich are quite extensive ridges of till parallel with the Ossipee mountains, and having a course about north-east and south-west. On the east side of the same mountains, from Moultonville nearly to West Ossipee station, is a nearly continuous fringe of large, angular blocks of porphyritic granite, such as occurs at the east part of the elevation, underlying the granitic breccias. These probably underlie the broad sand plain of the Bear Camp river. Green mountain in Effingham is an isolated elevation; and I thought at first these granitic blocks at the base of Ossipee came from it, having been transported northerly. Rock of similar character occurs on Green mountain, but it does not seem to have been carried so far to the north. There are many large blocks of granite close by Ossipee pond, at the cross-roads about three miles north-west from Green mountain, which probably came from the Ossipee mountains, moving east or south-east. The largest one seen is 21 feet long, from 7 to 14 high, and 16 wide. Green mountain has a great thickness of hard, compressed till upon its northern flank, extending more than half-way up. At its base are some small ridges turned up parallel to the mountain, with the steep slope against the mountain, as would naturally be the case if their origin were what is here indicated. The till has usually a smooth surface, the loose blocks having been removed from it by the sliding. Some of the striated blocks, as at James S. Smith's, have been deposited in stratified sand. A boulder of Ossipee granite over the sand near here is 12 feet in diameter. The thick deposit of till is wanting on the south side.

Between Greenfield and Bennington are rows of boulders on the south-west side of a large lenticular hill.

Crotched mountain in Francestown and Bennington may be taken as a good example to illustrate the presence or absence of this class of deposits. An attempt to make a thorough examination of this elevation was frustrated; but evidences of the moraines were seen on the south-west side, consisting of many large, rough blocks and ridges on the north-east side of Whittemore pond. Similar blocks occur on the road nearest the mountain on its south side. The north-east slope of this elevation is smoothed, as if there had been a sliding over the till; but I have not seen the nature of the ground at the very base. As it appears uncultivated when seen from a distance, it is probable that so much rubbish has been pushed into it from Crotched as to make the land difficult of tillage.

The north side of the New Durham and Brookfield Moose mountain is thickly strown with large boulders of granite and schist, obscuring the ledges.

Various evidences of local sliding appear in the city of Manchester. One is at the corner above Brook street. Three layers appear in an excavation, the two lowest apparently resembling the upper and lower till. The uppermost—of a lighter color—may have slid down the hill about the time of the termination of ice action. It is a material that runs like porridge when wet. Other similar cases have been removed in grading for new streets. The north-west side of Company hill for over a mile shows many moraine-like windrows parallel with the ridge. These contain more or less boulders, and are properly referable to this latest action. Perhaps these moraines should have some connection with the north-west course across the rock near the Amoskeag granite quarry. On the south-east side of this hill, back of the granite quarries, as we pass the pest-house on Bridge street, is another local moraine. Bald hill, near the east line of the city limits, furnishes other illustrations, there being two north and south lines of moraines upon its east side. On the south slope of this hill are numerous blocks of granitic gneiss, situated in a north and south course, reaching nearly to the railroad. One of them is 20 feet square. These seem to have been derived from Bald hill. Other lines of moraines occur at the south-east base of the Reservoir hill, where the fragments are angular.

In Grafton are high hills extending from Prescott's easterly along the Springfield line. A brook flows easterly along their base, turning at an acute angle by a small pond, and entering Smith's river at Grafton station. Within this acute angle are piles of drift parallel with the easterly hills south. These may be the rubbish sliding down from the south across the brook.

In Chester, two hills near each other seem to have crowded this loose detritus into the valley between. First is the gneiss hill in the north part of the town; and we find a line of blocks on its south-east side from Wm. S. True's round to near North pond, a distance of two or three miles. There may have been additions to the moraines from the smooth hill south, upon which Chester village is situated.

In Deerfield, the direct road from Candia to the Centre across a long ridge in the south part of Deerfield descends to a large branch of the Lamprey river, and then rises much towards the Centre. On both sides of this stream are lines of moraines parallel with the brook, and also with the valley. These are excellent illustrations of this class of moraines. How far these moraines would extend along the valley, can be known only by further search. Our traverse is simply one section across them. Other examples occur in crossing the parallel tributary one mile south from the Centre.

The hill north of Pawtuckaway pond in Nottingham, on the road nearest to and around the mountain, shows lines of moraines parallel to the hill south-west from Quincy pond. Some of the blocks are 12 or 15 feet in length.

In the north part of Fremont is a round hill less than 200 feet above the plain, around which are local moraines, especially upon the north-west side. There is a large field of big blocks near the Baptist church on the east side. The east and west road in the north parts of Fremont and Brentwood lies over numerous drift ridges and moraines essentially parallel with the stream and the higher land to the south. These may not be local.

In Kensington, the lenticular hills in the north-west part of the town show good illustrations of the local moraines in the form of many rough blocks and small mounds on the north-east side near M. Hobbs's. Some of the blocks are 20 feet long. This example is of a large moraine deposit by the oldest drift, serving for the centre of dispersion of blocks at the close of glacial work.

South of the railroad at Raymond for two miles, chiefly east from the village, are many moraines of all sizes, referred to local action, in case the high land to the north is regarded as the locality from which they have come. They are as conspicuous as most moraines left by the older drift.

The foregoing are sufficiently numerous to call attention to the subject of these late movements of earth analogous to glaciers. In this same connection, I desire to describe certain other glacial phenomena of more consequence, but which usually do not prove themselves by any striæ or embossment. They are better examples of ice action than what has just been described, but like them, move down valleys and hillsides, smoothing the ancient hill, and pushing along boulders. It is the action of glaciers upon material that had already been moved by the continental ice, and which belong to a later period still than the valley movements and local glaciers. All these glacial movements are described here before speaking of the boulders and moraines, so that the subject of glaciers may be treated as a unity. This class of facts was first brought out by the late Prof. L. Agassiz, who spent much time in their study about Bethlehem. I had the pleasure of seeing the phenomena he describes, under his guidance, and can testify to the fidelity of his statements. He communicated to me many other speculations concerning the existence of glaciers in the neighborhood, some that I could not indorse; but it is very gratifying to see that he published only what would stand the test of the most rigid scrutiny. It is to be regretted that he was unable to make other further publications, as intimated in the following paper. I subsequently searched the mountains, and other parts of the state, for facts confirmatory of Agassiz's views, both as to the special case described and to the further development of similar classes of facts in other localities. These facts I will present after reproducing the original paper referred to. I find evidence of a local glaciation in the White Mountains, not in the style of sculpture and moraine advocated by Packard and Vose, but in the peculiar form of evidence first suggested by Agassiz. It required a genius like his to point out the proper method of investigation.

Twenty-three years ago, when I first visited the White Mountains, in the summer of 1847, I noticed unmistakable evidences of the former existence of local glaciers. They were the more clear and impressive to me because I was then fresh from my investigations of the glaciers in Switzerland. And yet, beyond the mere statement of the fact that such glaciers once existed here, I have never published a detailed account of my observations, for the simple reason that I could not then find any limit or any definite relation between the northern drift and the phenomena indicative of local White Mountain glaciers; nor have I ever been able since to revisit the region for more careful examination. This year, a prolonged stay among these hills has enabled me to study this difficult problem more closely, and I am now prepared to show that the drift, so-called, has the same general characteristics on the northern and southern sides of the White Mountains. Whatever, therefore, may have been the number of its higher peaks which, at any given time during the glacial period, rose above the great ice sheet which then covered the country, this mountain range offered no obstacle to the southward movement and progress of the northern ice fields. To the north of the White Mountains, as well as to the south, the northern drift consists of a paste more or less clayey or sandy, containing abraded fragments of a great variety of rocks, so impacted into the minutely comminuted materials as to indicate neither stratification nor arrangement or sorting, determined by the form, size, or weight of these fragments. Large boulders and pebbles of all sizes are found in it throughout its thickness, and these coarser materials have evidently been ground together with the clay and sand under great pressure, beneath heavy masses of ice, for they have all the characteristic marks so unmistakable now to those who are familiar with glacial action,—scratches, grooves, furrows, etc. These marks are rectilinear, but they cross each other at various angles, thus showing by the change in their direction that the fragments on which they occur, though held for a time in one and the same position while these straight lines were engraved upon their surface, nevertheless changed that position more or less frequently. A few flatter fragments with more angular outlines show only one kind of scratches, having evidently been held for a longer time in the same position. This drift, however it may vary in its mineralogical components in different localities, exhibits everywhere the same characteristic treatment over the whole country, from the shores of the Atlantic to the Rocky Mountains, and beyond. In the White Mountain region it has the same mineralogical character north and south of the range, and rests everywhere upon the well known *roches moutonnées*,—in one word, upon the planed, grooved, polished, and scratched surfaces of the rocks underlying it.

Observation has taught us that materials such as those described above, so combined, exhibiting the same characters in their surfaces, and having the same diversity of composition and absence of all sorting or regular arrangement, occur now at the bottom of the great glaciers of our time, and nowhere else, being found between the ice and the rocks over which it moves,—the result, in fact, of the grinding action of advancing glaciers. On account of their unvarying position, I have called these deposits "ground moraines," because they are always resting upon the rocky floor of the country, between it and the under surface of the ice. Our typical unaltered so-called *northern* drift is synonymous with the ground moraines of the present day, differing only in its greater extension. It is in fact a ground moraine spreading over the greatest part of the continent. All its characteristics, identical in every detail with those of the deposits underlying the present glaciers, show that it can only have been formed under a moving body of ice, held between it and the underlying mass of rock. The great ice sheet of the glacial period which fashioned the drift must therefore have been coëxtensive with the distribution of the latter. It is very important to distinguish this drift from the moraines formed under other circumstances, and from the so-called erratics and perched blocks. Moraines, as commonly understood, that is, lateral and frontal moraines, consisting of loose materials collected along the sides and at the terminus of a glacier, always indicate, and, where undisturbed, actually define the margins of a moving mass of ice; whereas, the so-called median moraines formed along the line of junction of the glaciers are carried upon the back or upper surface of the ice, and always consist of angular materials, the shape and arrangement of which are determined by their mode of accumulation. Just as among the glaciers of the present day we discriminate between ground moraines, lateral, frontal, and median moraines, so must we also distinguish between the same phenomena in past times. The glacial period had also its ground moraines, its lateral, its frontal, and its median moraines, its erratics and perched boulders. But the huge ground moraine of the earlier ice time stretched continuously, like the ice sheet under which it was formed, over the whole country, from the arctics to the Southern states, and from the Atlantic to the Rocky Mountains. I do not speak of the western slope of the continent, because I have not examined it personally. The great angular erratics of that period were scattered irregularly over the country, as the few large boulders are scattered on the upper surface of a glacier now. It is the contact of the more limited phenomena of the local glaciers which succeeded this all-embracing winter (their lateral, frontal, median, and limited ground moraines and their erratics), with the more wide-spread and general features of the drift that I have been able to trace in the White Mountains this summer. The limits of this paper will not allow me to do more than record the general facts, but I hope to give them hereafter more in detail, and with fuller illustrations. The most difficult part of the investigation is the tracing of the erratics to their origin; it is far more intricate than the identification of the origin of ordinary drift, or of continuous moraines, because the solution of the problem can only be reached under favorable circumstances, where boulders of the same kind of rock can be followed from distance to distance, to the ledge *in situ* from which they were detached. Now, in the neighborhood of the White Mountains, we find, beside the typical or northern drift, large erratic boulders, as well as lateral, frontal, and median moraines. A careful examination of these shows beyond a doubt that they came from the White Mountains, and not from the northern regions, since they overlie the typical drift which they have only here and there removed and modified. A short description of the facts will leave no doubt upon this point.

The finest lateral moraines in these regions may be seen along the hillsides flanking the bed of the south branch of the Ammonoosuc, north of the village of Franconia. The best median moraines are to the east of Picket hill* and Round hill. These latter moraines were formed by the confluence of the glaciers which occupied the depression between Haystack and Mt. Lafayette, and that which descended from the northern face of Lafayette itself. These longitudinal moraines are particularly interesting as connecting the erratic boulders on the north side of the Franconia range with that mountain mass, and showing that they are not northern boulders transported southward, but boulders from a southern range transported northward. But by far the most significant facts showing the great extent of the local glaciers of the White Mountain range, as well as the most accessible and easily recognized, even by travellers not very familiar with glacial phenomena, are the terminal moraines to the north of Bethlehem village, between it and the northern bend of the Ammonoosuc river. The lane starting from Bethlehem street, following the cemetery for a short distance, and hence trending northward, cuts sixteen terminal moraines in a tract of about two miles. Some of these moraines are as distinct as any I know in Switzerland. They show unmistakably by their form that they were produced by the pressure of a glacier moving from south, northward. This is indicated by their abrupt southward slope, facing, that is, toward the Franconia range, while their northern face has a much gentler descent. The steeper slope of a moraine is always resting against the glacier, while the outer side is comparatively little inclined. The form of these moraines, therefore, as well as their position, shows that they have come down the Franconia mountains. A few details concerning their location may not be out of place, in order that any visitor interested in the facts may readily find them without a guide. The ground to the north of Bethlehem slopes gently northward, and is not wooded for about half a mile from the street. Following the lane above mentioned, the first moraine reached skirts the edge of the wood, and is near the houses of Mr. Phillips; there are four others more or less distinct before reaching a little trout brook called "Barrett's brook." The lane descends more rapidly towards the brook than before, and where the descent begins to be steep the eye commands the space between the brook and a higher ground on which stands a house owned by Henry McCulloch. Over that interval six very fine moraines may be counted, one of which is perhaps the finest specimen of a terminal moraine I have ever seen. Beyond McCulloch's there are five more, not quite as distinct. The ground beyond the termination of the glacier of the Rhone in Switzerland is celebrated for its many distinct concentric terminal moraines; but here we have a field over which, within the same area, a larger number of such moraines may be seen, and I believe that a pilgrimage to this spot would convert many a skeptic to the true faith concerning the transportation of erratic boulders, especially if he has seen the glacier of the Rhone, and can compare the phenomena of the two localities.

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* Since called Mt. Agassiz.—C. H. H.

The Littleton road from Bethlehem, and the roads to Franconia Notch from both these towns, frequently intersect terminal moraines. Those familiar with the topography of the Franconia range, and its relation to Picket hill and the slope of Bethlehem, will at once perceive that the glacier which deposited the front moraine to the north of Bethlehem village must have filled the valley of Franconia to and above the level of the saddle of Picket hill, making it at least fifteen hundred feet thick, if not more; thicker, in short, than any of the present glaciers of Switzerland. It will be observed, also, that as soon as the northern portion of that glacier had retreated to the wall which encircles the Franconia valley on the north, the glacier occupying henceforth a more protected valley within the ranges must have made a halt, and accumulated at this point, that is, south and west of the saddle of Picket hill, a very large terminal moraine. This moraine actually exists to the present day, and is one of the most characteristic features of the distribution of erratics in these regions. From the moment the glacier was reduced to the level of Franconia bottom, it must suddenly have vanished entirely from the whole valley; and thus it happens that no other large terminal moraines are seen between that just mentioned and the higher range of Franconia.

Moraines similar to those observed on the northern side of the White Mountains exist also on their southern side in the vicinity of Center Harbor. Lateral moraines may be traced at the foot of Red hill, a little above Long pond; also, along Squam lake. Median moraines are very distinct near Center Harbor hotel. Terminal moraines are also numerous near Center Harbor, and in the neighborhood of Meredith. At the southern end of Red hill the lateral moraines trend westward, and show their connection with the terminal moraines. These facts, taken in their relation with those enumerated above, show that there were local glaciers on the southern as well as the northern slopes of the White Mountain ranges, moving in opposite directions,—those on the northern slope moving northward, and those on the southern slope moving southward. I have seen no evidence thus far of these northern glaciers extending beyond the range of hills which separates the Ammonoosuc river from the Connecticut river valley west of Lancaster, nor have I traced the southern glaciers beyond Lake Winnipiseogee. Traces of an eastern glacier moving westward may be seen near the Twin Mountain house; but I have not examined that region with sufficient care to give minute particulars.

All these moraines and traces of local glaciers overlie the typical or northern drift, so-called, wherever the latter has not been swept away by the local glaciers themselves; thus showing that the great ice sheet was anterior to the local glaciers, and not formed by a spreading of preëxisting glaciers. At least, wherever I have recognized traces of circumscribed glaciers in regions where they no longer exist, it has always appeared to me that the minor areas covered by ice were remnants of a waning sheet of greater extent. If the glacial period set in by the enlargement of limited glaciers already formed and gradually spreading more and more widely, as Lyell and the geologists of his school suppose, the facts which would justify such a view are still to be made known. I have not seen a trace of them anywhere. On the contrary, throughout the ranges of the Alps, in the Black Forest, the Vosges, as well as in the British islands, in Scotland, Wales, and Ireland, I have everywhere satisfied myself that the more extensive the glaciated areas indicated by polished surfaces and moraines, in any given locality, the older they are when compared with glacial phenomena circumscribed within narrower limits.

It therefore follows from the facts enumerated above, as well as from a general consideration of the subject, that the local glaciers of the White Mountains are of more recent date than the great ice sheet which fashioned the typical drift. On another occasion, I hope to show that the action of the local glaciers of the White Mountains began to be circumscribed within the areas they covered, after the typical drift had, in consequence of the melting of the northern ice sheet, been laid bare in the Middle states, in Massachusetts and Connecticut, after even the southern portions of Vermont, New Hampshire, and Maine had been freed, and when the White Mountains, the Adirondacks, and the Katahdin range were the only ice clad peaks in this part of the continent.

When in their turn the glaciers of the White Mountain region began to melt away, the freshets occasioned by the sudden large accumulation of water remodelled many of these moraines, and carried off the minute materials they contained to deposit them lower down in the shape of river terraces. I have recently satisfied myself, by a careful examination, that all the river terraces of the Connecticut river valley and its tributaries, as well as those of the Merrimack and its tributaries, are deposits formed by the floods descending from the melting glaciers. What President Hitchcock has described as sea-beaches and ocean bottoms near the White Mountain and Franconia Notches, as well as in the Connecticut river valley and along the Merrimack, have all the same origin. The ocean never was in contact with these deposits, which nowhere contain any trace of marine organic remains.—*American Naturalist*, vol. iv, p. 550.

Local Glaciers in the White Mountains.

I will now present whatever additional facts may be known respecting the existence of former glaciers radiating from the White Mountain highlands. We have seen that my father and Prof. Agassiz agreed as to the nature of the glacial markings upon the mountains,—that they belonged to the older and continental sheet, a south-east movement proceeding up hill whenever obstacles made it necessary. The markings described by Packard and Vose, claimed to have been the result of local glaciation in the Peabody valley, have been shown to belong to the older movement. The others mentioned by Packard in Jackson are properly local, and will be described presently.

In order to prove that glaciers have radiated in all directions from the White Mountains, it is necessary to find evidences of northerly or north-west motion. Evidences of valley movements towards the south-east can easily be referred to the general south-east movement, modified slightly by the topography. If nothing else could be found, the doctrine of the existence of local glaciers would depend upon unreliable evidence. The researches of Agassiz about Bethlehem were the first in this direction in New Hampshire. He found evidence of a movement opposite to that of the general drift. Hence this must have been different from the common drift, and, taken in connection with the other features described, it was found to have been local, and existed in the decline of the ice period after the continental sheet had mostly disappeared. The action was rarely sufficiently energetic to score the ledges. Agassiz does not rely upon that class of evidence in maintaining his position. The ice of this Franconia-Bethlehem movement has passed over ledges, but has not smoothed or striated them. The boulders which went southerly in obedience to the south-east movement were simply pushed back towards their source; and we find very few cases of their protrusion beyond their starting-point. I will first add whatever observations I can in elucidation of this specific example, and then describe the other observed facts seen nearer the mountains.

The starting-point of this glacier was in the prominent valley back of Eagle Cliff, on the north-west flank of Mt. Lafayette. This was visited by my father in 1851, and a sketch of the phenomena seen described soon afterwards.* It appears that in 1850 a powerful rain soaked the débris in this valley so that it slid a considerable distance downwards, and left deposits analogous to moraines, but did not materially engrave the ledges.

> At the head of the slide we saw a mass of naked gneiss rock many rods wide, mostly denuded of soil, and much of it also of several layers of the rock, which had slid downwards, and were strown along the sides of the ravine for at least two miles. This naked surface, at its upper part, had a slope of about 38°. Lower down, however, it was much less, for the most part, and at its termination the descent was slight. * * * It was just such an example as I had long wished to find. An enormous mass of detritus, probably from ten to twenty feet thick, and in some places two or three rods wide, composed of irregular fragments of all sizes, from twenty feet in diameter down to sand, had been driven forward over a rocky surface two miles long. What, now, was the effect upon the rocky floor? Did it score and striate the floor, as was done by the drift agency, as some suppose would be done by the crowding forward of detritus by the power of water? I found it was not so. The rock in place was smoothed but not striated, except in a few places, perhaps in the slightest manner. The fundamental rock passed over is gneiss, but it is traversed occasionally by veins of granite, and towards the upper part by dykes of trap several rods wide. They are such rocks as in various places retain distinct markings of the drift action. The beds of detritus produced along this slide are so closely like those of glacial origin that we may call them *moraines*. They are larger and more distinct than I have seen on any other slide. All along the borders of the ravine are ridges of blocks, gravel, and sand, sometimes twenty feet high, lying in as much confusion as is possible, and making it difficult and even dangerous to go into or out of the ravine over the loose and crumbling ridges. At the lower end of the slide is a large terminal moraine, by which the river has been forced to seek a new channel. This terminal moraine is, in fact, double; that is, an old moraine lies in advance of that produced by the slide of 1850, the blocks of the two being easily distinguished by the appearance of recent or more ancient erosion. In short, the appearances along this gulf are almost precisely what they would be if a glacier in one of the valleys of the Alps should melt away. And when examining it, I had no doubt that the slide was produced by the advance of a mass of ice; yet I noticed that, in some places, the lateral moraine was driven in among the trees without affecting them. In some places near the bed of the slide I noticed the stumps of trees, perhaps six inches in diameter, that had been broken off by the descending mass.

This valley was regarded by Agassiz as the source of that glacier. In confirmation of it, boulders of Franconia breccia like the ledge composing Eagle cliff, have been found near J. McDonald's, in Franconia, at the end of a road on the direct line between the cliff and Bethlehem street. The distance of their transportation is about two miles, and no locality of this rock is known to exist nearer McDonald's than Eagle cliff. Many of these blocks are four feet in length. The ledge near here does not show any ice marks from the local glacier, but there are appearances upon it of the usual south-west movement of the neighborhood (page 211). North of McDonald's, towards Gale river, the surface of the drift is smooth and nearly flat. This is to be explained by the passage of the ice over it, as in Bethlehem. Near the western edge of this flat expanse is a moraine running N. 27° W., about 20 feet high and 40 rods long. It is thought to have been connected with this Bethlehem glacier, as a medial or lateral moraine. The hill slopes rapidly just west of the moraine, and has many quite large boulders scattered over it.

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* *Am. Jour. Science*, ii, vol. xiv, p. 73.

Between Bethlehem street and Littleton is a Baptist church, near which I observed boulders 15 feet long, 10 wide, and 10 high, whose source is estimated to be from 300 to 500 feet to the south up hill. Their transportation down this slope I ascribe to the same local glacier.

There are numerous moraines commencing a few rods east of Littleton railroad station, probably put in their present position by ice of this or a related glacier. The eastern slope of the hill between Bethlehem street and station is thickly strewn with large boulders, of material similar to the nearest ledges. Their position is suggestive of transportation down the Ammonoosuc from the east. As similar rocks occur as far as the Twin Mountain house, it is not unlikely that the Ammonoosuc glacier brought them there; but further study is required to demonstrate the proposition.

Ammonoosuc Glacier. We have a few facts in regard to the movement of rocks down the Ammonoosuc valley, probably caused by a local glacier. The ice transported boulders far below Bethlehem station, so that abundant proof exists of the existence of a glacier close by the gneissic blocks just mentioned, on the east slope of the Bethlehem hill. The source of this movement was in the large valley occupied by Concord granite, between Fabyan's and the Presidential range. Many large blocks of a coarser-grained granite than ordinary lie upon the slope of Mt. Deception, just opposite the Fabyan house, and along the turnpike for a mile easterly. These have not travelled far, having been derived from the south base of Mt. Deception. One piece is 22 feet long, 14 high, and 10 thick. Those 6 feet in length are common. The fragments are too far removed from the mountain to have accumulated merely by gravity. A similar moraine is cut by the railroad just below the White Mountain house at the head of the falls in the Ammonoosuc.

The recent clearings disclose a sharp, conical moraine south of the Mt. Pleasant house, perhaps 20 feet high, and very different in character from the neighboring mounds of esker and river gravel. The many large granite blocks, where the railroad approaches near the Ammonoosuc river, above Mt. Pleasant and near the upper falls, are also like a local moraine.

In the fields east of the Twin Mountain house there are hundreds of boulders of Mt. Deception granite, often 12 feet in length. The underlying rocks, for the four or five miles distance between the Twin Mountain house and Fabyan's, are of very different material. Hence this is an example of materials transported westerly a distance of four miles. This cannot have been done by water,—the blocks are too large. A local glacier sliding over the more ancient drift must have been the agent of transportation. This lateral moraine east of the Twin Mountain house is quite conspicuous, and the most readily accessible of any examples known. It may be seen from the train, a short distance east of the station.

Just west of Rounsevel & Colburn's saw-mill, midway between the Twin and White Mountain houses, I found a large block of granite, in 1871, nearly 12 feet in diameter, and about square, closely resembling a handsome variety of granite occuring on Mt. Willey, and further south. A second smaller one exists in the neighborhood. I have never found this particular kind of granite north of the Notch in ledges, and as it occurs with the Conway granite near Mt. Willey, it is probable that these blocks descended the New Zealand valley, starting from the west side of the same mountain. Other boulders, seemingly from the south, are a few of Chocorua granite near the Crawford house, in which Prof. Dana discovered grains of chrysolite. I know of no ledge to the north of their present situation from which they could have been derived, while similar ledges abound farther south.

Examples of transported boulders of Albany granite are more decisive of a glacial movement down the stream. From the mouth of New Zealand river nearly to Bethlehem station are numerous blocks of this granite, six feet in length. This rock is in place on the New Zealand river, but not on the Ammonoosuc. Hence the fragments must have moved down the stream (also Little river, in Carroll), and being too large for water transportation, require the agency of a glacier. Rude striæ, supposed to have been made at this period, occur near the Wing road in the river. The boulders are found as far south as North Lisbon. I obtained a specimen there weighing about eight pounds. No search has been made for them lower down. Their location in the river, and angular shape, indicate transportation by a local glacier. About half a mile above Bethlehem station the valley is almost closed by a large hill of till, with some stratified layers on the outside. This eminence resembles a moraine.

On Little river, about four miles above its mouth, is a slide worthy of mention. For a distance of 50 rods the ledges are bare, where they have been exposed by the sliding, commencing at a point and expanding to 20 rods width. At the base of the hill are 10 rods space as long as the width of the slide, full of fallen trees with their trunks mostly arranged in convex order, opposite the direction of transportation. No other features of local motion were apparent in the Little River valleys, largely because a dense forest prevents them from being seen, or else the power exerted in this slide was not sufficient to score the exposed ledges. It is probable that the Bethlehem and Ammonoosuc glaciers united and flowed down the latter stream several miles below their junction.

River Moraines. In the Saco valley the tributary streams have brought down immense masses of large boulders that would be called moraines elsewhere. They cross the main valley like terminal moraines. The larger the tributary the more important the deposit. They are particularly conspicuous at the mouths of Bemis and Davis brooks, Nancy and Sawyer's rivers. The latter deposit has been cut through by a railroad excavation. This is the most conspicuous example. On descending the valley by the carriage-road, we approach a broad expanse of the terrace where are one or two farms, and also the turning off of the branch railroad to Livermore. The highway ascends a sort of terrace, and the railroad cuts into it, rising somewhat. At the excavation, the nature of the material is well shown, consisting of smooth boulders, from pebbles to boulders two and three feet in diameter. The bed of the river shows similar detritus. The stream is so violent in high water that these boulders are pushed downwards, and as the force of the current abates the detritus accumulates by the sides. The amount brought down is so great that it rises higher than the meadow, and thus we have a deposit analogous to that of the levee near the mouth of the Mississippi. The tributary stream causes this very coarse deposit to form a ridge reaching nearly across the Saco valley, and at right angles to it. Hence it simulates the terminal moraine of a glacier, and might easily be mistaken for one, if the connection between its presence with the tributary were not noticed.

Below Sawyer's rock this coarse material exists in such amount that it is difficult to decide whether it should be called a glacial or a river moraine. The rubbish has accumulated in the eddy behind the ledge, and can be called by either name. It must be 50 feet thick, and cover half a square mile of surface. It seems to have been excavated at Stillings's old hotel stand by Albany brook from the south, and the moraine between this stream and Upper Bartlett station is of large size. The railroad cuts through a similar bank on the north side of the Saco, about opposite the mouth of Stony brook in Hart's Location.

I have already mentioned a few examples of striæ on the ledges in the valley of Saco river and its tributary, Duck pond, which are referable to a local glacier. Through most of Bartlett the land is flat, as if all the rubbish that usually occurs in the form of terraces had been washed out. The soil is sufficiently good to enable farmers to cultivate it extensively. For a mile and a half along Burbank and Cow brooks, there is a ridge of coarse material comparable with a lateral moraine. It is where detritus would be naturally deposited, as the river begins to bend northwardly. Where the Saco runs northerly to meet Rocky branch is another moraine pile, at the angle formed by the meeting of these two streams. Below this point the valley widens into the broad gravelly meadows of Lower Bartlett and Conway, which have been previously described (p. 143). Dr. Bemis points out at the base of Mt. Crawford a granite block, as much as 12 feet in cubical dimensions, now in the middle of the meadow. This came from the cliff 500 feet above the plain a few years since, and after striking the meadow bounded a distance of 10 rods to the spot where it now lies. A series of moraines occurs at the sawmill on Rocky branch, and for half a mile above.

Ellis River Glaciers. A recent visit to the main Ellis river and the Wildcat Branch in Jackson enables us to describe the markings left by the ice in its descent. Dr. Packard has called attention to them in a paper cited above. He gives scarcely any details, and relies upon the course of the striæ, mainly, for the proof of the existence of the local glaciers. These have been credited to him in the table of striæ. One remark is of importance: "Riding up the Conway valley, up through Bartlett to Jackson, we observe moraines innumerable rising high up the sides of the valley, and, covered with boulders, revealed more distinctly in all the cleared lands. Above these moraines rise rounded and embossed rocks, while the evenly terraced valley shows that the river, then a series of broad lakes, reärranged and re-sorted the compressed materials composing the mounds left by the melting glacier into finely, evenly stratified fresh water deposits." I noted some of these moraines in Bartlett, or the edge of Conway, in the woods south of the Interval station. Mr. Bigelow's fine summer residence is upon one of these moraines; and the blocks are quite numerous among the pine trees further south. The striæ S. 60° W., observed by Vose on the south side of Mt. Pequawket, must have been made by a branch from the east. After reaching the Ellis valley, there is a proper moraine of a local glacier just below Goodrich falls. In the edge of Jackson is a ridge in the middle of the valley, about an eighth of a mile long, with many large boulders upon its surface. Small cuts in it show the presence of some boulder clay. This reaches nearly to the bridge across the Ellis river, shortly below the entrance of the Wildcat Branch, and in a proper medial moraine. On reaching the village of Jackson, the valley divides; and I will first refer to the glacial traces seen on the main stream. There are large moraines upon both sides of the valley north and south of a large boarding-house, perhaps an eighth of a mile west of the falls. Those south are at the base of Cobb's hill, and are less important than those on the other side. About two miles up the valley are lateral moraines. About opposite the mouth of Miles brook the ledges show striæ running down stream, and have been abundantly rounded, producing the phenomena of embossment. Better examples occur higher up. The last notable example of the same is to be seen close by N. H. Cook's, or the last farm-house in Jackson. There is here somewhat of an expanse, while above the descent is greater, and no intervals can be seen. A careful examination of this valley will disclose many more facts, both in the settled and forest portions. On reaching the height of land in Pinkham Notch, we approach the Peabody valley, and find marks of a movement up the valley towards Ellis river. The ice travelled a little west of south, north of the water-shed, but east of south in the Ellis valley. It is difficult to say that the movement in the Ellis valley was disconnected with that in the Peabody. It is likely that, in the earlier glacial times, the course was first west and then east of south, while in the decline of the period the ice ceased to flow from the Peabody into the Ellis valley. There may have been a local northerly movement in the Peabody valley, also, as suggested by the enormous terrace, in the south part of Gorham (p. 210).

The marks upon the Wildcat Branch have been more carefully examined, although the scoring of ledges is less common than on the main stream. At the top of Jackson falls are many moraines supposed to be terminal, and of the last valley movement. An examination of their composition shows them to be a miscellaneous accumulation of ferruginous earth and rough stones of granite and schist. There has been no arrangement of the different sorts by aqueous deposition; it is an unstratified pile. Its red color arises from the extreme oxidation and hydration of the mass. The material corresponds closely with that of the upper till of the older drift, which we shall describe more fully presently. The origin of the two deposits is believed to be the same. These moraines cross the valley, and are about 140 feet above the bridge between the hotels. The next set of terminals jut out into the valley half a mile beyond, and probably once stretched across it. Near J. Gale's is another set, 215 feet above the bridge. On the west side of the valley, large, rough blocks of stone are common, while the east is smooth. A fourth moraine appears at the two Elkins's houses, a mile and a quarter from the bridge. The fifth example is near D. Gray's, shortly before coming to the road leading towards Black mountain. These moraines are lateral, and there is a slight depression between them and the hill west. There are many rough blocks near the road on the east side of the valley, on the south flank of Black mountain, which are to be regarded as lateral moraines, opposite to those mentioned at Gray's, but higher up.

A sixth set of moraines crosses the valley at a new saw-mill near Mrs. E. Gray's, two and a quarter miles north of the bridge, and 255 feet higher. Above this point the valley keeps the same contour as far as Johnson's mill, 150 feet higher, and more than a mile distant. No well marked local phenomena display themselves here, nor higher up, along the carriage-road. Possibly a search in the wooded tract adjacent to the stream might reveal something interesting above Johnson's. A cut in the drift here shows it to belong to the lower till. Opposite L. Wentworth's, nearly a mile above Johnson's, is an esker, or kame, 1,000 feet long, which may have originated during the melting of this glacier, and is thus one of its evidences. On reaching Grant's (Breck, on map) the present road ceases, but the valley might be followed further to the north-west. Here are striæ quite varied in direction. The face of the rock is smoothed in the direction of the valley a trifle west of south, crossed by faint irregular lines S. 33° and S. 83° E. These would be explained by calling the smoothing the direction of the ice down the valley, and the striæ caused by a local tributary sliding from the western flank. The top of the ledge, where there is freedom from local currents, displays the course S. 44° E., the normal direction of the ancient drift, pointing nearly to Mt. Washington. The Wildcat shows other interesting phenomena of local action further north, but I have not been able to examine them. I will add notices of them from Nowell and Sweetser. The slide described by the first properly belongs to one of the tributaries of the Peabody river glacier.

W. G. Nowell has given estimates of the position and dimensions of a slide upon the west side of Carter Dome, Vol. I, *Appalachia*, p. 83. I condense his account. The date was the same with that described upon the west side of Tripyramid. Mr. Thompson, the proprietor of the Glen house, lost his life in this freshet, while managing affairs at his saw-mill. The top of the "hopper," where the sliding commenced, is 1200 metres from the summit. It descended N. N. W. 300 metres, dropping 110 metres; then fell 140 metres in a course of 400 metres due north; next moved 500 metres W. N. W., descending 110 metres, and continues only 100 metres further. For the principal part of the last 700 metres the ledge is perfectly bare from 30 to 60 metres in breadth, and has piled up at its base about twenty square acres of rubbish that had come down the mountain. The greatest angle of descent, 42°, occurs in the upper and lower of the four sections, and the least angle of 18° is in the third section from the top. The minimum widths of the four sections are 10, 15, 20, and 30 metres; the maximum 15, 20, 30, and 90 metres. The minimum depths of the excavation were 15, 10, 5, and 3 metres; the maximum 18, 15, 10, and 10 metres.

Mr. Sweetser, in his guide-book, speaks of a line of boulders in the Carter Notch which may have had some connection with glacial action. At the south entrance of the Notch is a lofty line of immense boulders, piled on each other in inextricable confusion, and affording some of the most remarkable rock scenery in the mountains. They are rugged and deeply pitted, like the rocks on the cone of Mt. Washington, and may have been derived from the crests of the adjacent peaks. One or two of these boulders are near seventy feet long each.

Returning to Jackson, we find a tributary of the Wildcat coming from the north-east, and uniting with it about a mile above the falls, which ought to show a few glacial traces. I found nothing very characteristic, unless it were a few boulders of a peculiar porphyritic granite. I think these must have been derived from the north, as nothing like them is known in ledges west of Mt. Baldface, or "Peaked," a summit so called by Packard, and not named upon our map. The striæ upon these mountains do not point towards Jackson, as they belong to the older set. Mr. Packard says,—"On the summit [of Baldface, where the striæ run S. 23°–28° E.] rest several angular boulders of a peculiar porphyritic sienite, containing curious oblong crystals of albitic feldspar. Our guide to their source—the trusty ice grooves—points to Peaked mountain;" and, by investigation, he found the rock *in situ* upon that eminence. The porphyritic boulders found by me did not come from the mountains mentioned by Packard, as the rubbish derived from them would have gone down the east branch of the Saco, joining the main stream in Lower Bartlett. Further search will develop evidences of the existence of this glacier in the east branch. Packard speaks of staurolite mica schist boulders on the north flank of Mt. Pequawket, saying "they must have been borne down on the back of the glacier from Mt. Washington." This is hardly probable, since the rock occurs on both the north and south sides of Pequawket, and the boulders are even more abundant on the south side of the mountain. Jackson Falls village is situated in a hopper-shaped depression considerably open on the west side. Pickett, Thorn, and Tin mountains constitute the north and east rims, Black and

Eagle the north and west sides, while Copp's hill on the west very nearly completes the circle, with rifts for the entrance of the ice from Wildcat and Ellis rivers. On nearly every side the material low down consists of an immense thickness of till, cut deeply by small streams. This deposit gives an evenness of slope to the hills about Jackson that is uncommon among the mountains. It is believed that the till is mainly of ancient glacial origin brought from the north-west, and that the latest ice movement smoothed it over and left many large blocks of stone and small moraines. The north slope of Pickett hill shows several examples of what appear to be local moraines. Packard speaks of a block of many tons' weight upon a hill near Goodrich falls brought in this way only a few rods. In the neighborhood are striæ pointing S. 17° W., as if connected with the valley movement just mentioned down the tributary of the Wildcat river.*

Pot-holes. In northern New England there are many examples of pot-holes worn in ledges far away from existing streams. These are believed to have been formed by currents of water derived from the melting ice-sheet, passing down the crevasses of the glacier. Those on the summit between different valleys were formerly referred to the agency of one of the rivers pouring over the divide into the other depression. Many of our examples are so situated that such a theory would not explain them. I append a list of the principal pot-holes that have come to my notice:

One 4 feet deep on top of Swett's mountain, Gilmanton.

One of large size in Wentworth. It is on the south-west side of Carr's mountain, from 300 to 500 feet above Baker's river.

In the "Flume," Dixville, I saw one, 4 feet in diameter and 7 feet deep, in the process of formation.

On a ledge exposed for 200 feet, near its south end, a conical one, 2 feet in diameter at the top, and about 2 feet deep. It is 125 feet above the river at East Weare, and in the edge of Dunbarton. It is called "Indian mortar" by the people living in the neighborhood.

The same name is applied to a pot-hole near the top of Beech hill in New Hampton, about 600 feet above the valley of Lake Wukawan. It is situated on the south-western peak, not quite so high as the other, and perhaps 15 rods south of and 40 feet lower than the highest point. There are no other evidences of water action on the ledges of porphyritic gneiss than this, and they fall off precipitously for 200 feet. The mortar is 2½ feet from the edge of the rock. It is not perfect, as a notch is gone on the south side, so that the cavity is shaped like a pitcher with the nose broken off. The width across the top is 1 foot 3 inches; depth, on the north side, 2½ feet; depth below the notch on the south side, 1½ feet. The bottom is rounded, and it is frequently filled with water.

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* I have assumed that Packard's observations were not corrected for the variation of the compass, as he does not say anything about it.

Mr. Upham has described the pot-holes of the Orange and Newbury summits, and Warwick, Mass., on pages 63–66.

At Amoskeag falls, Manchester, on the Merrimack, are several pot-holes; one of them is 12 feet in diameter and 25 deep.

The "Purgatory," on the line of Lyndeborough and Mont Vernon, shows other pot-holes. The stream—10 feet wide—winds spirally through a narrow chasm, and then falls 15 or 20 feet into a large pool. Both the spiral course and the pool are to be classed with pot-holes, and there are several small examples above the main cataract. A cave below is thought to have originated from ordinary disintegration through freezing.

Local Movements in Vermont. Besides the tributaries of the Connecticut glacier already mentioned, I will speak briefly of the other valley movements occurring in the area of our map. There has been an easterly movement up the valleys of the Lamoille, Missisco, and Winooski, perfectly distinct from the general south-east progress of the continental sheet. It seems to have been a modification of the south-east current, caused by the contour of the country, and in no sense a local glacier. They are to be compared with the movement of the ice up the valley of the Peabody river (p. 208).

I found excellent local glacier phenomena in the valley of Lincoln brook, a tributary of Mad river in Warren. In Plainfield, boulders of granite seem to have been transported north-westerly to the main village from Harris and Goshen gores. Other cases are probably Trout brook in Montgomery, and near Lake Memphremagog from the west.

Lake Basins.

One of the evidences of glacial action is seen in the hollowing out of basins in the solid rock, which are now occupied by lakes or ponds of fresh water. If one travels around the border of certain lakes, he will discover that it is everywhere rock-bound. In considering the possible methods of excavation of such a basin, some cannot be accounted for except by glacial action. We should consider, first, whether it might be a synclinal basin; second, whether it might result from the removal of a soluble mineral like limestone. Running water excavates rocks only where a descending current can act; hence it could never remove anything from beneath its level. Ordinary lake ice cannot excavate beyond a few inches below water level. Nor could the ocean, if it were present, excavate any deeper. There is no other agent left for us to employ, except the glacier. When this starts, having a strong force to urge it onwards, it will plough out rocks in its descent, and then move up hill. This sort of denudation is fitted to excavate lake basins.

There are numerous examples of these basins excavated out of the rock for lakes and ponds in our state. I purposed to make a catalogue of them, to be presented here, specifying all whose outlet flowed over ledges, and those where till or modified drift constitute the barrier. I found, on studying the subject, that a barrier of lower till would keep in the water as well as a ledge, so that the enumeration of ponds kept in by barriers of rock or till made little practical difference as to the stability of the water. Furthermore, a lake may be essentially kept in by a rock barrier, while the drift spreads an additional obstacle to the flowage outwards; and, as scarcely any examples could be found of ponds kept in by barriers of loose materials, it may not be necessary to present a formal catalogue of the nature of outlets, citing, instead, a few familiar examples.

Geological treatises make mention of Runaway pond in Glover, Vt., where a sandy barrier led to the sudden outrush of the water, after an attempt made to increase the size of the outlet by excavation. Similar floods have occurred recently by the removal of artificial dams, as in the well-known Mill River disaster near Northampton, Mass. We have a record of a similar flood on the Mascomy river, occasioned by the bursting of the original barrier of the lake at East Lebanon. The loose material was not abundant, so that little damage resulted. The Northern Railroad company have since renewed the barrier with better material. It is an interesting circumstance to recall the ancient barrier of till about a quarter of a mile below the present outlet (p. 216), whose removal in pre-historic times may have caused a great freshet. In Warren, the signs of the bursting of a barrier in ancient times are very distinct. A gravel ridge like a kame crossed the valley of Black brook, damming the stream and producing a pond. What circumstances destroyed this barrier are not known, but the former existence of the pond attracts universal belief. Another case is in the edge of Lyman below Young's pond. A new road follows the stream above the saw-mill, and the gravel hills on both sides for a quarter of a mile look as if they had been cut apart within the memory of the inhabitants. An old shore line, marking the former height of the pond, is still quite conspicuous. As one passes the south end of Station pond in Springfield, he is at a loss to see why the water does not immediately make an opening for itself towards New London. Upper Beech pond in Wolfeborough is an example of an existing pond kept in by a deposit of loose gravel (p. 128). There are many instances of ponds in gravel plains kept in by loose materials when the amount of water is not sufficient to lead to a sudden removal of the barrier. Such are indicated on the general map by the absence of any outlet.

Our largest lake,—Winnipiseogee,—must be a rock basin, although no ledges appear at its outlet (p. 121). The land falls off abruptly for about 1400 feet at the Weirs, in slopes say 600 feet long on the north-west, and 800 on the south-east of the middle of the channel, the amount of the fall being nearly 80 feet. As one looks at this from the east it resembles a gorge excavated by running water, and it would not be strange if the till had once been continuous across the present outlet. In that case the outlet would have been from Alton bay towards the Cochecho river. The present channel has been deepened about a yard by the Lake company. About 25 feet of till has been removed by erosion at the outlet of Newfound lake.

The majority of our ponds have ledges at their outlets. Those who are interested in the subject can ascertain whether a given example has been excavated from the ledges by observing the nature of the outlet. It is very often the case that no ledge is visible about a pond, save where the water discharges itself. If any dams are constructed upon loose gravel or sand, it will be well for those interested in the integrity of the works to examine them from time to time.

DISPERSION OF BOULDERS.

The second part of our subject relates to the removal of fragments of stone from their original ledges, and to any peculiarities that may be observed in their position, shape, size, distance and direction of transportation, etc., including the various kinds of moraines. The striation is believed to correspond in direction with the course taken by the fragments in their travels. The stones usually proceed in right lines from their sources, at first in large rough blocks, then showing more abrasion and less size, till they have been reduced to pebbles or coarse gravel, and finally no traces can be seen of them.

This method of dispersion shows miners how to search for veins of valuable ores. If blocks of copper or lead ore show themselves temptingly, the country may be searched in the direction of the drift common to the neighborhood, usually visible on ledges near by in striæ. Let the country be carefully explored in the direction whence the stones have proceeded, and when no more can be found, the soil may be removed, and the veins will show themselves. This method of search, both for veins and beds of rock, has been constantly employed in the conduct of the geological survey, and the principle has never been found incorrect. The existence of many peculiar ledges would never have been discovered had not attention been first drawn to certain singular boulders.

If we were to take up the drift deposits one by one, or town by town, and specify what kind of boulders occurred, and what seem to have been their sources, much labor would be required, and the details would not be interesting. When the geology of the state is perfectly understood, those conversant with it will be able to say whence every stone found anywhere within our limits has been derived. The general law of the dispersion of the fragments may be thus stated: the boulders have been transported in the direction in which the ice of the glacier period moved, as indicated by striæ. By consulting our table of striæ, where nearly every town is represented, those seeking to learn the origin of interesting stones in their neighborhood may learn the probable point of compass in which to travel to find the source of their specimens. I will endeavor to state presently any exceptions to the above rule known to exist.

The teachers of the institute at New Hampton have interested their classes in this subject, and the young people have left behind monuments to themselves in the form of large boulders transported by the drift, found in their neighborhood, and presenting some strange or unique feature. I noticed a large block of the handsome porphyritic gneiss found in the east part of the town, and two boulders of andalusite schist, with coarse and fine crystals, one of them apparently from Carr's mountain. These specimens ornament the grounds of the institute, while other minerals are exhibited under glass.

In order to give some idea of the distribution of boulders in the state, I will select a few examples, and describe carefully the kinds of rock found, their size, probable origin, and distance of transportation. In the same connection, other interesting features illustrating the general subject may be mentioned incidentally. Some generalizations may follow the description of localities.

Boar's Head.

In the middle of Hampton Beach, a mound of drift about 1300 feet long and 45 feet high, rises very conspicuously to view. It is the well known *Great Boar's Head*, visited every summer by thousands of people for the enjoyment of sea air and bathing. Though small, it may be regarded as a true lenticular moraine, isolated from all visible connection with any other mass of till, by a distance of nearly two miles between the nearest points. It has been exposed to the wearing action of the sea from time immemorial, and consequently has lost a considerable portion of its mass. The clayey portion of the till is washed out, leaving the stones, and consequently the former size and shape of the mound is clearly indicated at low tide by the remnants. From the extreme point of the cliff these boulders extend south-east for 400 feet. Their northern limit is about a quarter of a mile north of the Boar's Head hotel; opposite the middle of the cliff the boulders are continuous 120 feet to the fucus growth, and a single stone projects out of the water as far again. If the hill were restored to its original dimensions, it would probably be 1800 feet in length by 350 in width, with a course about N. 35° W. It was steepest on the south side. Mr. S. H. Dumas, the proprietor of the hotel, thinks there has been no wearing away of the hill of any consequence for many years. The landing-place for boats on the south side has been constructed as it is now for the past forty years. If a new one were desired, no change of position would be required; so that the erosion on that side has been very inconsiderable. The present slight curve in the beach north of the hotel he remembers to have been straight once.

Mr. Joseph Dow, of Hampton, says a measurement of the bluff in 1875 showed that a length of one rod at the point had disappeared since 1826; and his impression is that a prominent stone, called Gunning Rock, near the end of the boulders, is farther removed from the bluff now than it was forty years since.

A view of this bluff from either side near the end shows finely the distinction insisted upon in this report between the lower and upper till. The sides of the bluff meet at the end, making a sharp edge, which dips towards the east at an angle of 60°. Fig. 54 is copied from a photograph, which shows the line between these divisions as plainly as in nature. The upper part has been broken away near its end, but its depth is nearly uniform over the whole plain, about ten feet, or a little less, at the end. This has its usual reddish-yellow in distinction from the bluish cast of the lower till. It is ferruginous, comparatively loose in texture, and contains rough stones, rarely any that have been striated, and the material is chiefly the slates found in place two or three miles distant. Being easily crushed, the upper till contains an unusual proportion of earth. Its resemblance to the upper till of Portland, Me., is obvious. The lower thirty-five feet of till is composed of very compact, gritty earth, slightly clayey, containing numerous smoothed and striated boulders, from grains of sand to fifteen feet in length. Many of the stones are in the condition of unstable equilibrium. The uncovering of the boulders by washing enables us to learn their nature, and refer them to their probable source. A careful description of the different kinds observed here will illustrate the origin and dispersion of all the boulders along the sea-shore. The most abundant rock is sienite, boulders 12 and 15 feet in length occurring occasionally. Those 6 feet long are common. They are all glaciated, but many have been smoothed since falling out of the bank by the waves. It is gray with a considerable sprinkling of white. I will group the boulders according to size. Of those about six feet in length are sienite, gneiss, trap, Pawtuckaway sienite, granite with blue feldspar, such as occurs in ledges at Frost's Point in Rye, crumpled

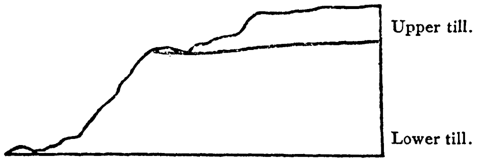


Fig. 54.—SECTION OF BOAR'S HEAD.

gneiss of the Manchester and Deerfield range. We found the following in pieces from three to four feet long: Sienite of Exeter, the most abundant as usual, and twelve different varieties; well defined gneiss, flinty slate, ferruginous mica schist, porphyritic gneiss (some blocks like that of East Concord, others like the New Hampton rock, the feldspar very abundant in double crystals), breccia of flint or indurated slates, sienite with black patches, dolerite, gneisses like the Laurentian, green augite rock, Concord gneiss, porphyritic gneiss with large garnets, saccharoid quartz, gabbro like that of Gilford, sienite with feldspar,—perhaps labradorite and fine gray granite. The following were found of less dimensions than three feet, down to pebbles: Montalban schist with blotchy mica, trap of various textures, granite like that of Barre, Vt., clay slate, andalusite mica slate, jaspery quartz, slates like those of Portland, Me., fine-grained reddish whetstone slate, Manchester gneiss, greenish sienite with porphyritic like parallel spots of gray quartzite, argillo-mica schist, reddish porphyritic rock or sienite, gray garnet rock, Albany granite, red porphyry, white breciated quartz porphyry, and Tripyramid sienite or diorite; also, reddish weathering limestone, such as occurs in eastern Maine.

The most conspicuous and abundant of these materials came from the sienite range extending between Dover and Exeter, and travelled from nine to fifteen miles. A few of this class may have originated in a range three miles nearer. Many of the slates came from the ledges inside of the sienite. No andalusite slate is known to exist within twenty-five miles. The Manchester gneisses have travelled certainly twenty miles; the others may have come from either a greater or a less distance. I know of no porphyritic gneisses, like those occurring here, nearer than forty-five miles in a north-west direction, while ledges sixty miles distant agree with them exactly. The gabbro found at Gilford is in boulders, so that I cannot certainly refer to their source. I find nothing that seems to have come from a greater distance than the Tripyramid sienite, at 77 miles. The porphyries may have come from greater or less distances, possibly from the Ossipee mountains. Others of the pieces are like rocks further north, but I cannot claim anything but the minimum distances. I do not specify many other distances that might be mentioned.

I have assumed the north-west to be the proper direction of dispersion, and nearly all the boulders seem to have come from that direction. The schists like those at Portland, Me., cannot be indisputably proved to have come from that quarter; but if there were evidence of a south-west current, I should refer to that locality for their origin. The most difficult fragment to explain is the piece of limestone about a foot through, found at the eastern edge of the cliff. It is drab colored, weathering reddish, and tarnishes quickly after exposure. There is nothing like it in New Hampshire, nor in western Maine. It is like some limestones from the vicinity of Machias, 190 miles distant north-east in an air line, or New Brunswick, much farther. I inquired whether ballast from schooners might not have been thrown out upon the beach; but those who have lived here for many years thought the stone could not have been brought in that way. Our conclusion is, that the stone came from the bank, more likely the upper than the lower division, and that its original source was towards the north-east. We need, however, confirmatory observations before throwing down the gauntlet in favor of this proposition.

DOVER.

The locality examined is the excavation in the kame half a mile north-west from the post-office, made by the Dover & Winnipiseogee Railroad, figured and described upon page 158. The previous example was in till; this is in material derived from the modification of the upper till, and the stones have travelled somewhat further than to their place of deposit from the glacier. The largest stone I have seen in any gravel deposit in the state occurs here, weighing sixteen tons. There are others two thirds the size of this, all of mica schist, with rough edges, showing only a short carriage. It is the rock of the neighborhood, and consequently the most abundantly represented among the pebbles. Others are fine-grained granites, Montalban schists, Concord granite, trap rocks, White Mountain porphyry, red porphyry (like that occurring upon Mt. Lowell), Albany granite, Tripyramid diorite, sienite (like that on Red hill), sienite with two kinds of feldspar, and the granite of Hart's Location, such as has been quarried on Sawyer's river. Probably ten per cent. of these stones came from the White Mountains, some of which can be shown to have been carried more than sixty-five miles. Perhaps most of them might have been derived from the Ossipee group, within forty miles.

Supposing the course of the striæ about S. 20° E., the Concord granite would have come from Farmington, 15 miles distant; the sienite from Gunstock, from 25 to 35 miles; the Montalban rocks about the same distance, or a little more.

MANCHESTER.

The city authorities have made numerous cuttings on various kinds of material within their limits, which can afford the most abundant information respecting the different kinds of material present in the drift. I searched for rocks transported a great distance rather than for the entire variety, so that my list is small. On Wilson's hill, at Lowell street, excavations have been made to the depth of from 12 to 15 feet, the finer sandy and gravelly portions separated by screens and carted away, leaving the stones and boulders, none of which exceed two or three feet in diameter. The excavation shows several features concerning the nature of the till better than anything seen elsewhere, and deserves to be shown in photographic illustrations. The examination was made before our decision to distinguish between the lower and upper till. The excavation probably exhibits both kinds of till, the upper a coarse, yellow gravel, from two to three feet thick. The surface of the hill is smooth, with scarcely any large boulders visible. There is a layer several inches thick of a sand overlying the gravel. Roots of pine trees have penetrated the earth to the depth of six feet. The lower till here contains many glaciated stones, including those that have come from the greatest distances. The material resembles clay, but, when pulverized between the thumb and fingers, is seen to be gritty, composed of siliceous rather than aluminous particles. This remark is applicable to very much of the drift deposits of southern New Hampshire, and explains our preference for the name *till*, adopted in this report for these accumulations, rather than *boulder clay*. The till here presents a laminated appearance, with horizontal partings, and iron oxide in the seams, evidently derived from water soaking down from the soil above. This laminated aspect is very common in the lower till, and is believed to result from the enormous pressure exerted by the presence of the ice-sheet. Two thousand or three thousand feet thickness of ice are adequate to induce these cleavage planes in the moist and slightly plastic earth. They cannot have come from deposition, as there has been no sorting of the material. Possibly some authors have mistaken these lines for stratification.

An uncommon feature is the presence of cracks and cavities, or what seem like such openings, one or two inches wide, filled with the upper gravel. Some masses of the lower till are entirely encompassed by them, so that in a section they appear like imbedded, irregular patches. The till occupies most of the area, the gravel occurring mainly in the veins. The section suggests the possibility of ice occupying the present position of the veins at first, and the subsequent infiltration of gravel after the melting of the frozen material. There are cases on record of large fragments of boulder clay transported by ice as if they were rocks. There might have been disturbances in the till, and the interspaces subsequently filled with gravel. This gravel does not show any cleavage structure like that of the lower till.

The larger of the boulders here are of granite, such as occurs within two miles. Those next in size are of the Manchester or Hooksett quartz, and mica schists of Andover and Franklin. Stones four inches long are composed of the Albany granite, and there are also two kinds of White Mountain porphyry. Similar White Mountain boulders occur in a railroad cut very near Massabesic lake, in a compact, elongated moraine, different from anything else in the vicinity.

The greatest distance of carriage indicated by these boulders is 68 miles. The mica schists travelled about 35 miles. The great bulk of the stones on Wilson's hill has come, therefore, from 35 miles and less.

A pebble of White Mountain porphyry has been shown to me by a resident of Nashua, who found it near his home. This must have travelled as much as 86 miles.

CONCORD.

An examination of the Concord kame showed many stones 8 to 10 and 12 inches in diameter, more than three fourths consisting of the Concord granite and associated rocks. I found, also, white quartz, ferruginous schists, porphyritic gneiss, trap, blue quartzite, hornblende schist, gneiss, and a possible example of Huronian schist from the Connecticut valley. Careful search failed to discover any rocks from the White Mountains. This indicates that the locality is too far west to receive contributions from the mountains. It suggests the probability of the transportation of those at Manchester and Nashua by the local Merrimack glacier. The ice from the White Mountains would meet the tributary glaciers from the west, and be compelled to slide upon the east side of the valley exclusively. Hence, whatever boulders came from the White Mountains would be found upon the East Concord or Manchester side of the valley.

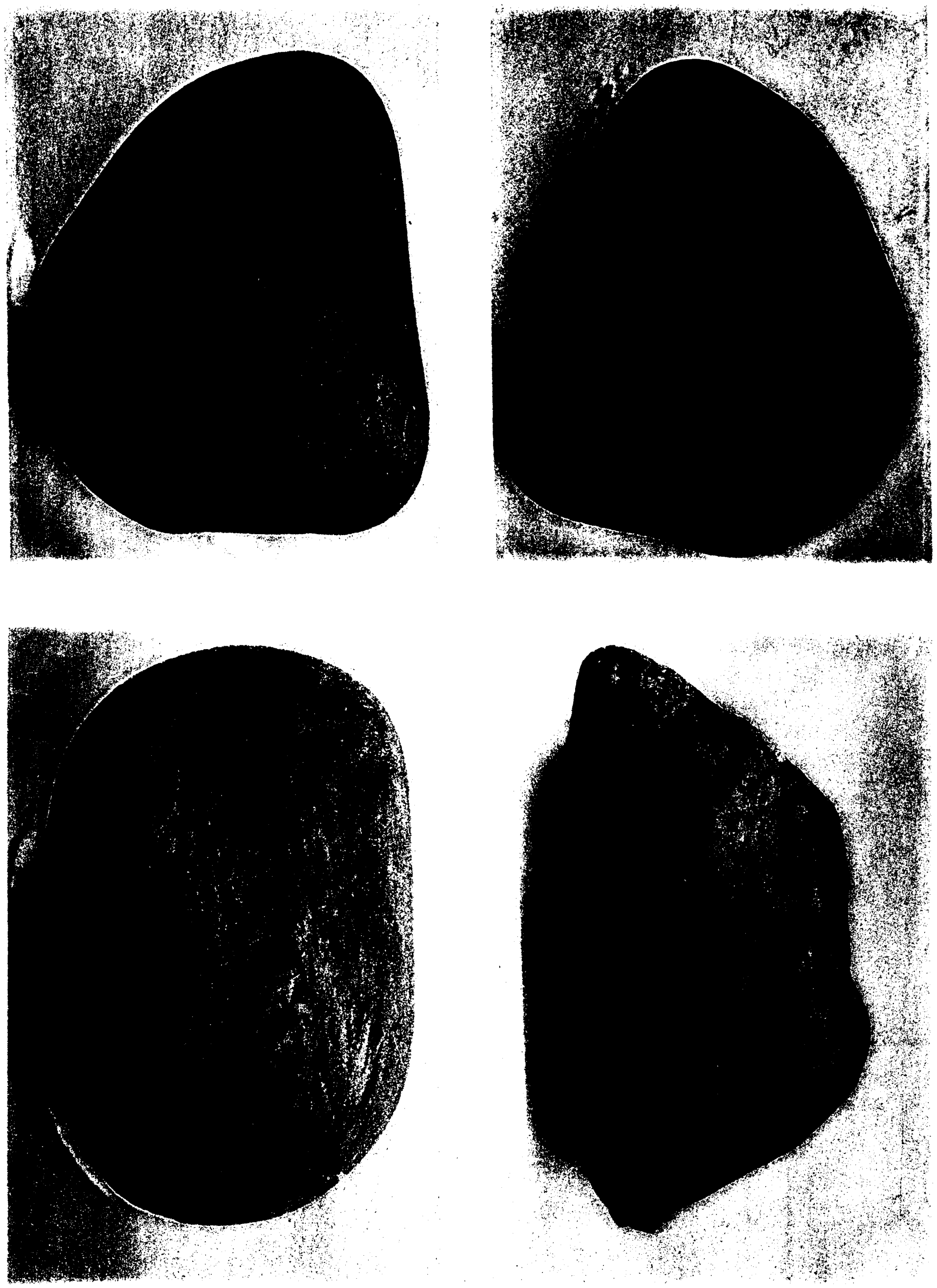
As the continental glacial sheet moved to the south-east, it follows that whatever White Mountain blocks are found in the lower till of the Merrimack basin must have been transported by a valley movement, unless the natural radial divergence from the mountains could have spread as far west as Manchester.

HANOVER AND VICINITY.

Passing over to the Connecticut valley, boulders of a different class present themselves to view, or those derived from Vermont. We also find a large proportion of them brought by the south-east current, although the striæ close by run west of south. This confirms our previous suggestions of the existence of both movements in this valley.

About two miles north of Dartmouth college the kame furnishes the following pebbles, the largest 10 inches in diameter: Barre granite, Bethlehem gneiss—both varieties, Huronian diorite, quartz schists with decayed layers, calciferous mica schist—several varieties, clay slates, hornblende schist, jaspery quartz, quartzite, decayed limestone. Elsewhere this ridge furnishes handsome pieces of red jasper, thought to have been derived from ledges west of the Green Mountains, a distance of 70 miles. The Barre granite has been carried 32 miles. The Bethlehem gneisses are in place one mile east of this kame for four miles, but they more probably came from Haverhill, 40 miles distant, unless transported down from the Jacob's brook glacier in Orford, on the east side of the valley. These pieces travelled on the Connecticut glacier. The various Huronian and the calciferous schists, and the slates, mostly came from the north-west, involving from a few rods to several miles of carriage.

Further east are heavy deposits of till composed of long travelled and much glaciated stones. Three of them are represented in the accompa-



GLACIATED STONES, HANOVER.

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nying heliotype. The two upper figures show the opposite sides of the same pebble—nearly of the natural size—of a mica slate, not of remote origin. On one side the striæ run at a small angle with the longer axis of the pebble. On the reverse side the lines are irregularly disposed. The lower left-hand view shows an argillaceous schist, derived from ledges five or six miles distant, of oblong shape, three inches long, and the striæ on both sides are approximately parallel to the longer axis. The whole surface on every side has been glaciated, some of the depressions being deeper than the others. The other view is of a Huronian schist, derivable from ledges three to twenty miles away, 12 inches long, 7 wide, and 3 thick. The upper end has been partially encrusted with carbonate of lime of more recent origin than the striæ. The opposite flat sides are scratched parallel to each other, and the longer axis of the stone. The ends are rough. This represents the shape and peculiarity of the striation of a majority of glaciated boulders.

The following varieties of material have been found in company with these heliotyped boulders upon the north side of Mink brook, about a mile east of the brick church at Mill Village: Hornblende schist, diabase, blue and gray quartzite, clay slate, serpentine, red quartz, red sandstone, and gneiss. The cliff is 40 feet high, the upper ten feet of upper till containing limestone.

These boulders must have been brought by the south-east current, some of them 65 or 70 miles. I think there is a notable absence of the Bethlehem gneiss among them. In the north part of the town the drift is very thick on the northern slopes. On following Mink brook to its source, in the south-east corner of the town, other similar ground-moraines occur. The same are more abundant south of Hayes hill in the edge of Lebanon. A tributary of the Mascomy has cut through this deposit, producing by erosion terraces of till. The surfaces of all these moraines are smooth, indicating the sliding of a glacier over them. Between Prospect and Corey hills is a smooth depression rising gradually to the curved water-shed between the stream flowing west and Mink brook. Scarcely any boulders occur on this basin; but after beginning the descent to Mill Village, coarse moraines and large rough boulders, twelve and fifteen feet through, abound. It would seem that the glacier broke off the fragments from the ledges of the smooth area, carried them to the brink of the declivity, pushed them over, and left them on the lee side of the hill. The contrast between the smooth fields south of Prospect hill and the rough pastures towards Mill Village is very strongly marked. On the hill north-east from Colburn's, in the edge of Lebanon, is another enormous accumulation of large gneissic blocks. On the College grounds, to the west of Culver hall, the surface was formerly covered by numerous large blocks of hornblende schist, sometimes ten feet across, derived from the adjacent ledges, and transported southerly by the Connecticut glacier. Excavations showed that some of them occupied an unstable position; if the earth were removed from their sides, they would topple over. It is a characteristic of till, that many of the boulders are so situated, and it bears witness to their method of removal. Had they fallen from an iceberg, they would rest with the centre of gravity *in equilibrio*. Now they are kept in a forced position, such as would result from the shoving along of a pile of débris, or such action as arises from the movement of a glacier. Underneath this clayey coarse drift the material is gravelly and less compact, derived from the gneissic rather than the slaty rocks of the neighborhood.

Quechee Railroad Cut. Between Hartford and Quechee villages the Woodstock Railroad has cut deeply into the lower till, affording the handsomest exhibition of the two varieties of till yet displayed in this region. The cut is 40 feet deep, three fourths of it being the lower member, very compact, full of small-sized glaciated stones cemented together by thick boulder clay. Every stone is striated. There are great numbers of the Burlington red sandstone, and many beautiful green serpentines. The most common are of gray quartzite. One was composed of a fossil coral. The red stones have travelled the greatest distance, from over the Green Mountains, about sixty miles. Concerning these and the similar ones at Hanover, it is to be remarked that they were raised over an acclivity of 3,000 feet altitude as well as transported a great distance. The upper ten feet of this cut is a typical locality for the upper till. There is the distinctively reddish-brown color, loose consistency, rough blocks common with an occasional striated one, and very many of the siliceous limestones of the neighborhood. None of the latter were observed in the lower till.

BOULDERS FROM MT. ASCUTNEY.

If different ice-currents have struck the ledges, and transported fragments in several directions, we shall expect to find the boulders quite far apart at a considerable distance from the source. As an illustration of this wide spread of materials starting from a small area, I will mention what is known about boulders starting from Mt. Ascutney, as their mineral character is peculiar, and not likely to be mistaken. In Claremont they are very abundant, about eight miles and a half distant, and the direction south-east. In Surry, on the west side of Thompson brook, in the north-west part of the town, Butler's rock, a boulder 20 feet long, 20 feet wide, and 12 feet high, came from Ascutney. The distance of transportation is 27 miles in the course S. 10° E. In Keene—west part—is a striated Ascutney boulder five feet in diameter, S. 8° E., and 35 miles distant from its source. G. A. Wheelock informs me of the existence of similar blocks at the west base of Monadnock, S. 20° E., and 42 miles; also one in Mr. Newton's garden in West Swanzey; 20 in Keene, the largest on Samuel Towns's farm; three in Surry; several in Alstead; very many at Paper Mill; and Dr. Prouty found one in Langdon, two in Gilsum, and one in Sullivan. Others are on Mr. Gilbert's farm in Walpole, two in Westmoreland, and one at Ashuelot. This last is nearly due south, and 45 miles distant. Another is at R. C. Fisher's in Hinsdale. The only other example in mind is in the north-east corner of Bernardston, a small stone 50 miles distant from Mt. Ascutney, and S. 4° W. in direction.

If lines were drawn from Ascutney to all these points they would correspond to radii. If the Claremont stones continue south-east, which seems likely, any occurring at the south state line in Pelham would be 85 miles distant, and 36 east of the Bernardston example. In this instance it is easy to account for the wide spread of the stones by the south-east current for some, and the Connecticut valley movement for the others. It is a question worthy of investigation, whether all boulders have a radial dispersion like these from Ascutney. The facts of this dispersion ought to be gathered in greater abundance, and compared with those obtained elsewhere.

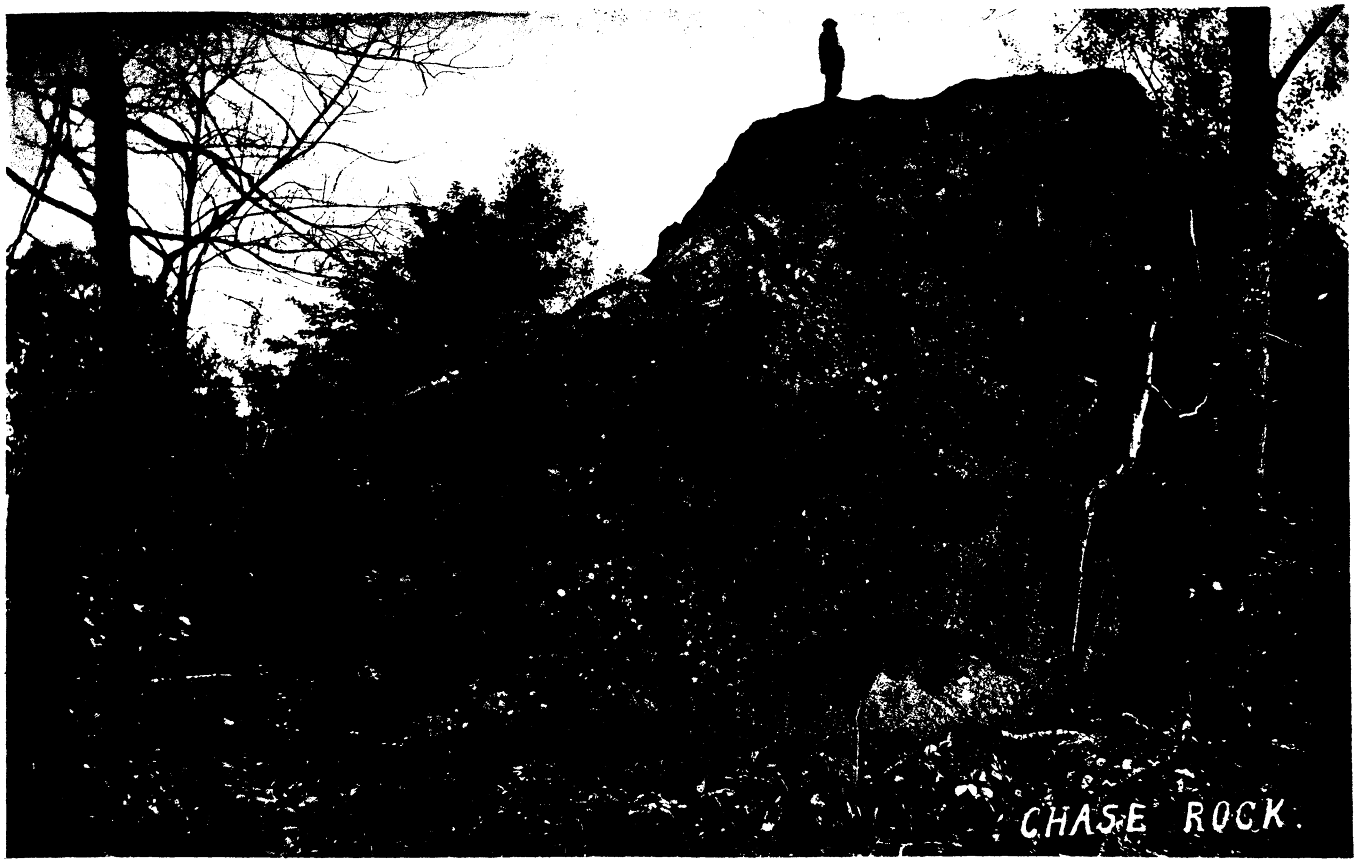
BOULDERLESS AREAS.

In New Hampshire no considerable regions are devoid of boulders, except areas of sand where the stones are concealed by deposits of later age. The nearest approach to a boulderless area is in the limestone regions of Cornish and Colebrook. In eastern Vermont the absence of boulders over the same formation is very conspicuous, as may be seen in passing up Wait's river and the east branch of White river. The boulders of the underlying rock decompose readily, and it is believed that though once as common as the average of granite blocks in New Hampshire, they have been disintegrated by atmospheric agencies, leaving very few signs of glacial work. Occasionally lines of granite boulders occur in this calciferous area, enough to show that the glacier did not slight it. Such boulders would furnish excellent studies of the radial dispersion of fragments, as their distribution could be easily made out.

On the contrary, some kinds of rock seem almost incapable of decomposition, and leave the fields profusely strewn with them. The porphyritic gneiss and the Exeter sienite areas are remarkable for the great amount of rough blocks of their own kind scattered over them. They are mostly those that have just started on their travels. Between Dover and Exeter the loose fragments of sienite scattered over the area occupied by this rock are numberless, and commence abruptly on the northwest side. One knows that he has reached the sienite rock by the numerous blocks of it seen long before a ledge can be found, it may be. I suppose their abundance is to be explained by their difficult decomposition.

LARGE BOULDERS.

Although our state is noted for the great abundance of boulders strewn over its surface, it is only quite recently that I have seen boulders in our limits larger than any of which mention has been made in the writings of American geologists. They were brought to our notice by His Excellency Governor Prescott. Regret had been expressed to him that no boulder had been found in the state equal in size to those known to exist in the neighboring states. As if he felt the credit of the state impaired by the imputation, he immediately searched the neighbor-



CHASE ROCK.

hood of Pawtuckaway mountain, and found a very formidable array of giant fragments superior to anything else described elsewhere. The celebrated *Pierre-a-bot* of the Jura contains about 40,000 cubic feet, weighing 3,000 tons; the Green Mountain Giant of Whitingham, Vermont, has the same cubical contents; the one formerly existing at Fall River, Mass., now destroyed, is estimated to have weighed 5,400 tons. The Churchill rock of Nottingham, shown in a heliotype at the beginning of this chapter, measures 62 feet long by 40 wide, and is estimated at 40 feet high. Making liberal allowances for irregularities in its dimensions, it contains over 75,000 cubic feet, weighs 6,000 tons, and is therefore nearly double the size of the Jurassic and Vermont examples. Bingham's rock at Smuggler's notch in Vermont is larger, but is so connected with a ledge as not to be properly esteemed an erratic. The Swiss example has been transported much farther than either of the New England boulders.

Churchill rock is on the south side of north Pawtuckaway. It lies in a valley not shown on our map by contours, starting at the middle of the Deerfield and Nottingham line where it passes over this peak, and pointing east to Round pond, made a part of Pawtuckaway pond upon the county map. This valley is half a mile long, and displays a very remarkable lot of large boulders and moraines. The commencement of the valley is a narrow notch in the sienite of the mountain, full 200 feet deep and narrow. The boulders seem to have been detached from the cliffs on either side of the notch, and then transported by the ice, perhaps, or local glacier, eastwardly. Within a few rods of the starting-point are several large blocks, worthy of special measurement anywhere except in their company. About an eighth of a mile down, too far to allow of their accumulation by gravity, are six large boulders close together, each one averaging 30,000–35,000 cubic feet. A little beyond them is Chase rock, 40 feet long, 40 feet high, and 30 feet wide. About a quarter of a mile or a little less from the starting-point is Churchill rock, and close by it two others, one estimated as equal to 30 feet in each direction,—27,000 cubic feet,—and the other ten feet longer, with the same breadth and height, or 36,000 cubit feet. On climbing the mountain north of Churchill rock, some large blocks are seen, which have been severed from connection with the ledge; one of them 50 feet long, slab-like in form, rests slanting against the hill-side, so as to make a natural shed for the cattle.

Churchill rock received its name sixty years since, from the circumstance that a lunatic of that name escaped from his keepers, and was discovered on top of this boulder. It will be seen that the rock is divided by a crevice, originally a joint, providing a space usually a few inches in width. Mr. Churchill must have crawled up through this narrow opening, doing, like other persons in his condition, what seems almost impossible. It was found necessary to fell a tree upon the rock to insure for the man a safe descent. The base of the stone is below the feet of Gov. Prescott, as represented in the heliotype, who stands the lowest down of the four persons seen in front. The top is midway of a pine tree with a trunk nearly two feet in diameter, and was thought, by some on the ground, to be 80 feet high.

Chase rock is well shown in another heliotype, with a profile view upon its summit of Erastus H. Chase, the proprietor of all these large boulders. Fifty years had elapsed since he climbed the boulder before. He took great enjoyment when a lad in climbing this rock. It is much more narrow when viewed from either end.

On passing nearly to Round pond, almost three quarters of a mile from the Pawtuckaway notch, we reach Ballad rock, so named from a preacher who used one of the projections for a pulpit in the early history of the town. A heliotype sketch of this is presented, showing two or three of the constituent boulders of this moraine, for it is a terminal pile of rubbish. It may have collected behind a ledge, though it is not always easy to separate ledges from boulders in this vicinity. The largest stone is 60 feet long and 40 feet wide, and ovoid in shape. The moraine itself is 150 feet wide and over 100 feet high. Five or six of the large boulders in it are readily discernible to the visitor. The view is somewhat defective, because of the difficulty of obtaining a good light in the forest late in the afternoon. This moraine is really more remarkable than the single large boulders, because it is composed of several pieces, each as large as Chase, if not Churchill rock. The ridge extends to the pond, and its base is crossed by the road.

We find, therefore, in this short distance of three quarters of a mile, certainly a dozen boulders, each exceeding 25,000 cubic feet in dimen-

BALLAD ROCK

sions. Their position requires the invocation of glacial action to account for their removal from the pinnacle or cliff from which they seem to have come. We could not have expected anything less than such a royal discovery, when the chief executive of the commonwealth set himself to search for something worthy of mention.

Vessel Rock. In Gilsum a large boulder (Fig. 55), called Vessel Rock, from its fancied resemblance to a ship, has long attracted attention. Dr. Jackson described it in his report, and thinks it came from a coarse granite ledge fifteen rods distant, according to G. A. Wheelock. The rock itself measures 46 feet in length, 24 wide, and 26 high, containing over 28,000 cubic feet. A piece was split from it by frost in 1817, measuring 33 feet long and 10 wide. The whole stone before splitting was said by Jackson to include 32,000 cubic feet, and to weigh 2,286 tons. Other large fragments of the same rock occur to the west and south. The building shown in the figure is a school-house. It is about a mile and a half south-west from the village.

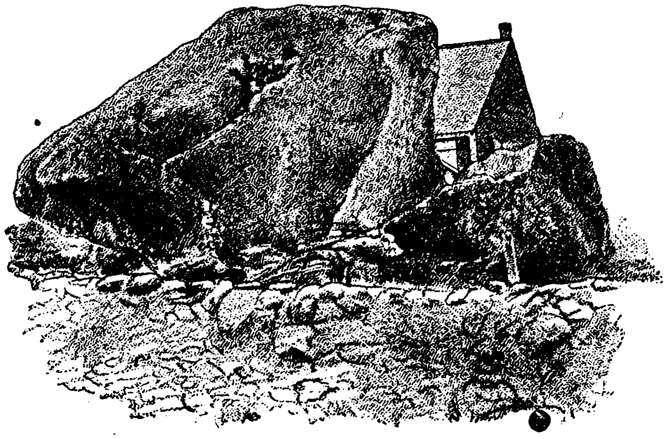


Fig. 55.—VESSEL ROCK, GILSUM.

Elephant Rock. This boulder is situated in Newport, within a few feet of the summit of Pike hill, fully 1,500 feet above the level of the sea. It is composed of graphic granite. Its length is about 29 feet, and its height not far from 23 feet. The rock is represented in Fig. 56.

Dr. Jackson says, in his report (p. 100),—"Some immense blocks of granite occur in Northumberland, on the estate of Mr. Mills Olcott, of

Hanover. One of them has the following dimensions: 30 feet long, 18 feet high, 27 feet wide, and contains 4,580 cubic feet. The other is 32 feet long, 6 feet high, 9 feet wide, and contains 1,152 cubic feet. It is a light-colored granite, of excellent quality for building. These blocks of granite are different from any rocks found in place in the immediate vicinity. The nearest granite ledge is one mile north of it, but is of a different kind. The original bed must be some distance to the northward."

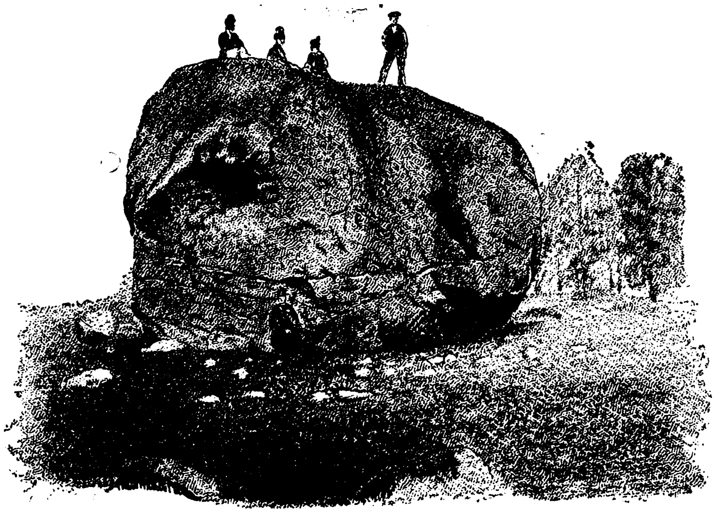


Fig. 56.—Elephant Rock, Newport.

Conway Boulders. Prof. E. J. Houston describes a large boulder, near the house of E. S. Stokes, North Conway, in much detail in the *Journal of the Franklin Institute,* Volume LXII, 1871. He calls it the Pequawket boulder. It is of coarse granite, with a preponderance of feldspar, considerable quartz, and very little mica. The general form is that of a parallelopiped, one of whose longer sides is partly buried. The length is 52 feet 6 inches; greatest breadth, 21 feet; greatest height, 33 feet 2 inches; and it is estimated to weigh 2,300 tons. Several large fragments surround the mass, seemingly once connected with it. One is 31 feet 3 inches long, 15 broad, and 21 high. On the south-east side is another piece 31 feet 7 inches long, 15 feet 3 inches broad, and 11 feet 7 inches high. Several spruces and beeches conceal the boulder from the road.

A moraine runs up the hill, N. 80° E. from the boulder, containing many large blocks. About 600 or 800 feet higher they average 12 by 13 by 15 feet. A few hundred feet below the Pequawket is another mass 31 by 18 by 21 feet.

There is another one called the *Washington Boulder*, represented in a heliotype. It is about a mile north-east from Conway centre, near Pine hill. Its dimensions may be expressed by about 30 feet high, 40 long, and 25 high. It is one of the notable objects of Conway, and is composed of the granite for which the town is famous. It cannot be shown to have travelled far.

Bartlett Boulder. This is not so noted for its size as position. It has the typical shape of glaciated stones,—15 feet long, 12 feet wide, 10 feet high,—and rests upon four smaller blocks. The entire assemblage rests on stratified sand: hence it was moved to its present position at the time of the melting of the ice. It is represented in a heliotype.

Ordination Rock. This is in Tamworth, west of the centre village, and has a flat top, reached by artificial steps, and is surmounted by a monument. It is 30 feet long, 30 feet wide, 12 high, and composed of Conway granite. It came from the north or north-east.

Flume Boulder. The photograph of the boulder suspended over the Lincoln flume, Volume 2, page 157, illustrates far better than words how this fragment happened to be caught, and now serves the useful purpose of keeping the walls of the chasm apart, and of affording amusement to thousands of summer visitors. No further description is needed above that already given.

Waterville. Several large boulders must be added to the list of attractions for this locality. Near Greeley's are some 8 feet high, of the celebrated ossipyte. Near Mad river are large granite blocks. The largest is just above the mouth of Greeley's Branch, or at the Swaseytown falls, 43 feet long, 25 wide, and 20 high. One lower down is 33 feet long, 27 wide, and 25 high. They are of Conway granite.

OTHER LARGE BOULDERS.

On crossing from Moultonville, in Ossipee, to the sources of Lovell's river, we observe a fragment of Conway granite near the height of land, 30 feet long, 27 feet wide, 18 feet high at the south end, and 10 feet high at the north end. There are no ledges near by, so that it has very likely been brought here from the valley north, and transported up hill, 200 feet of vertical height.

In Hanover, upon the west flank of Moose mountain, east of E. Wright's, is a boulder of hornblende schist 22 feet long, 12 wide, 16 high, from which a considerable piece has been separated by frost. It may have travelled less than a mile. A boulder of Vermont granite, perhaps half the size of the foregoing, is said to have been taken from the top of Moose mountain and made into monuments for the cemetery. On Gen. Jackman's farm in Bath, there was, a few years since, a line of large Huronian boulders averaging 12 feet through, arranged like a lateral moraine. The first cucumbers seen in Bath were raised upon the top of one of them. Near Jones pond in Raymond is a boulder of twisted gneiss 30 feet long, 25 feet wide, 22 feet high at one end, tapering to 8 at the other. In this neighborhood, Raymond, Epping, Nottingham, similar large boulders are frequent. Those derived from Pawtuckaway are quite noticeable for twenty miles to the south-east. Several large ones are located upon Governor Prescott's farm. South of the station at Raymond is a boulder of white quartz, transported several hundred feet, 48 feet long, 39 wide, 24 high (30 feet at one end), with two pine trees on top, one 16 inches in diameter near the base. This compares favorably in size with some of the Nottingham examples. Near Brackett's station in Stratham are two sienite boulders, each averaging twenty feet in three directions, that have come two or three miles. Near Bronson's house in Landaff are boulders of conglomerate 30 feet in each of the three dimensions. They probably came from some undiscovered layer not far distant.

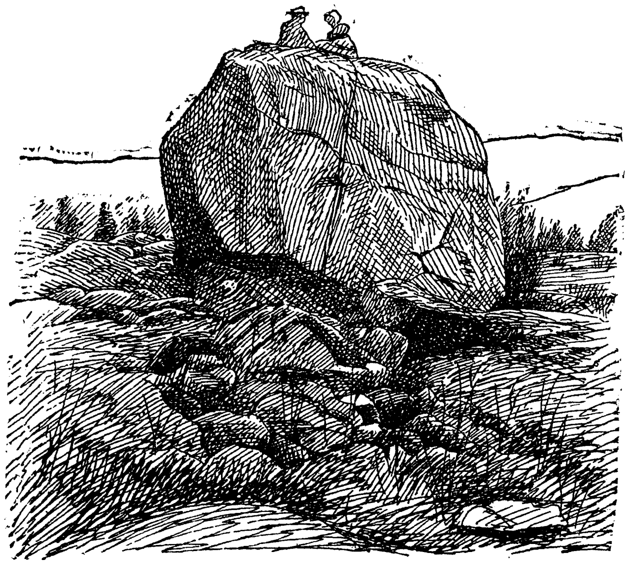


Fig. 57.—Great Rock in Wentworth.

BARTLETT BOULDER

GRAVEL CUT, CRAWFORD HOUSE

Fig. 57 represents Great Rock in Wentworth, with Mt. Carr in the distance. Two persons seated upon the summit illustrate the size of the boulder.

In the west part of Fremont are a great many boulders, each from 12 to 15 feet long. The same is true of many other portions of Rockingham county, as near Windham junction, on Clyde hill, where mention is made of one weighing 500 tons.

Rocking-Stones.

When large boulders are left on ledges they may be so evenly balanced that a slight effort only is needed to make them oscillate. Such cases as have fallen under my notice are the following:

On Shirley hill, Goffstown, just east of Uncanoonuc, there are two. One of them is 8 feet high and 42 feet in circumference. The dimensions of the other are not stated. With them is a third large stone.

Governor Prescott speaks of a rocking-stone upon Mt. Pawtuckaway. Seneca A. Ladd, of Meredith village, informs me of the existence near his residence of a small rocking-stone.

Up Corey hill in Hanover, half a mile east of Dartmouth college, is a rocking-stone 12 feet long, 10 feet wide, 5½ thick, containing about 480 cubic feet. Its of Bethlehem gneiss, and has been transported only a short distance.

On a high hill, about a mile west of Newport village, is a rocking-stone weighing not far from 25 tons. It is about 9 feet high, egg-shaped, and stands upon its larger end.

Upon Russell Clifford brook in Warren there is said to be another, of these stones, with a tree growing on the top.

Boulders on top of high mountains. Those on Mt. Washington have been mentioned; see page 208. On top of Dixville mountain is a boulder of hornblende rock 5 feet long. Has travelled several miles. Cannon mountain shows a porphyritic gneiss block 4 feet in all directions, which may have come from Bald mountain, about two miles distant, and been elevated 1650 feet. Mt. Kearsarge exhibits a great many boulders of the same material, 5 feet long, that have been elevated more than those on Cannon. Granite boulders are common on the top of Moosilauke; also, Bethlehem gneiss, Lisbon Huronian, Montalban mica schist, Coös quartzites, besides the common rocks of the mountain. Of these, the Montalban may have come from the north, Essex county, Vt., forty miles away; the Huronian not necessarily more than twelve miles;

the quartzites a less distance. The origin of the Bethlehem gneiss is not clear;—if from west of north, it may have come from the north part of Haverhill, very near. If the current west of south brought any material to the summit, the boulders would naturally have come from Bethlehem, less than twenty miles away. Upon Mt. Lafayette are many boulders of the darker variety of Bethlehem gneiss, derivable either from the east or west of north. A fine-grained granite, Huronian hornblende, and gneiss occur about fifty rods below the top. Forty feet below the top, on the south side, is a boulder of porphyritic gneiss. None of them are necessarily great travellers, say twelve or fifteen miles from the north or north-west. The Sugar Hill staurolite is found at the Eagle lakes, indicating six miles travel to the south-east. This is different from the striæ on the mountain, which runs west of south. Both forces must have operated here. At the first tank on the Mt. Washington Railway, say 3,000 feet altitude, are stones of Essex county, Vt., pargasite and delicate staurolite; at least, no other localities of these minerals are known, a distance of twenty-eight miles north-west. At the third tank, 5,800 feet, are pebbles of Lancaster or Huronian rocks, that have come nearly twenty miles. Near the top of Mt. Madison are handsome granite boulders, of such material as occurs a few miles northerly. On Red hill, Moultonborough, are fine-grained granite, probably from Waterville, black mica schist like that of the Coös group, trap, hornblende, Montalban and Lake gneisses, all in place near by, except the second, which is unknown short of forty-five miles to the north-west. Mt. Mote shows slate from the upper Saco valley. From Mt. Chocorua I obtained a sparkling mica schist, which may have come either from the north-west or the north-east. Lovell's mountain in Washington shows mica schist and gneiss boulders, which cannot be definitely located. On top of Mt. Ascutney are argillaceous schist and Huronian diorite pebbles, the first from the north, the second probably, not necessarily, from the same quarter.

On the top of the north Twin mountain are boulders of Bethlehem gneiss from the north-west, ten to fifteen miles. The slide on the north side has many Huronian fragments, that have come about twenty miles. Cherry mountain summit shows Bethlehem gneisses from Jefferson, the next town. There are boulders of porphyritic gneiss on top of Mt. Gunstock.

MISCELLANEOUS ITEMS.

A few other facts concerning the dispersion of drift and other glacial phenomena are worthy of preservation, although it is not possible to state them systematically. I have placed several hundred specimens of boulders found in various parts of the state in the Hanover museum, properly catalogued, so that it may be consulted by those who wish to verify the statements of this report, or obtain hints of facts not alluded to in it. Many of the specimens represented strange information at the time of the collection, not now valuable except as illustrating the fact of dispersion. Others are from noted boulders, or collected upon the tops of mountains, or represent the supposed underlying rock in the absence of ledges.

On the west slope of Gardner's mountain, near Hunt's, are boulders of the Craftsbury concretionary granite (petrified butternuts), with ordinary granite and hornblende rock from Vermont.

In West Littleton are two houses (Wheeler), and others in Lancaster, built of the Vermont granite brought to New Hampshire by glaciers.

Mt. Carmel in Pittsburg, as seen from Dixville mountain and Mt. Washington, presents a good example of a large eminence rounded on the north-west by the ice striking it, and rough on the lee side where the force of the ice had abated.

Between North Lisbon and Streeter pond a mass of till more than 100 feet thick has been cut through by the south branch of the Ammonoosuc, and fine sections are exposed upon it. Ledges are scarce near the river.

Rocks full of segregated veins weather unequally, often affording curious shapes. It is quite common to see these stones placed in conspicuous positions upon walls or in dooryards by the farmers, who take pride in their exhibition. The siliceous limestone of the mica schist, the finer-grained sienites, and the segregated veined variety of (Lake) gneiss afford the best examples of this erosion. I recall examples in Bath and Center Harbor, resembling piano-stools and mushrooms.

The importance of soapstone has led to noting the position of boulders of it in certain parts of the state. Those in Pelham, Keene, and at Island pond in Hampstead, have not been referred to their source. The original bed is yet to be discovered. In New Boston, by the school-house west of S. Dodge's, are several large boulders, distant about four miles in the direction S. 20° E. from the bed on Mt. Misery, Weare, their probable source. The same occur in Weare, at the south foot of Mt. Misery.

Serpentine boulders are common but not abundant in Keene. One in Walpole weighs about 350 pounds.

The numerous gneissic boulders in West Epping led to the discovery of a small area of this formation in the Lamprey river.

There is an enormous quantity of porphyritic gneiss boulders about the village of Northfield, Mass. Until otherwise proved, they may be supposed to have been transported from the area of this ancient gneiss in Winchester by the Connecticut valley glacier. It is also interesting to note the derivation of the Triassic conglomerate. The largest constituent is an oval-shaped piece of granite. Several are two feet long; the rest are smaller. Twenty-nine specimens represent these pebbles in the museum. They all came originally from the formations to the north-east and north,—none from the west side of the Connecticut. The most abundant are the Montalban schists and granites. Others are the Vernon gneiss, hornblende schist, Coös schists and granites, and several varieties of quartz from veins.

Boulders of sienite occur at Freedom village, whose origin is unknown. On a high hill in Eaton are boulders of black quartz porphyry, probably from Albany, twelve miles north-west. At the east line of Madison are samples of Albany granite and fine-grained sienite from the same region. At the outlet of Newichwannock lake are black porphyries from the Ossipee mountains to the west, presumably.

In Center Harbor, between Squam and Winnipiseogee lakes, also further south, are many large pebbles of Huronian and Coös rocks. Assuming them to have come down Baker's river, they have travelled 40 miles. With them are pieces of the Calciferous mica schist limestone, seen also on Mark's island and in Grafton. These two travelled at least 50 miles.

At the sea-shore on Cape Elizabeth river are numerous glaciated pebbles of a porphyry like that of Mt. Pleasant in Bridgeton, or Burnt Meadow mountain in Brownfield, about 40 miles north-west.

At Littleton, west of the village and near Echo lake, Franconia, are pebbles of andalusite mica slate, with acicular crystals, like a rock in Granby and Victory, Vt. The course would have been only a few degrees east of south.

Handsome porphyritic gneiss occurs on the east line of Effingham. Its source is not clear, whether from the small Albany and Chocorua range, or from the north-east in Maine. The same rock in Haverhill probably travelled west of south from the Wing Road neighborhood.

A piece of clay slate in Lyndeborough, if from the north-west, travelled 42 miles. Mr. O. E. Randall has shown me pebbles of red sandstones, like that of the Potsdam west of the Green Mountains, picked up in Chesterfield. These are like those mentioned as occurring commonly about Hanover, page 260,—the distance probably greater—75 or 80 miles.

About two miles up Imp brook in Bean's Purchase, almost under the very countenance of the Imp, are loose blocks 50 to 60 feet long. Between Mts. Pleasant and Franklin are many granitic boulders, brought up from the Ammonoosuc valley beneath, 10 feet square. Jasper pebbles are common about Connecticut lake and Stewartstown. They probably came from Canada. The same occur upon Mormon hill in the north-east corner of Lyman. There is in the lower part of Hinsdale village a boulder about as large as an old-fashioned school-house, of which the traveller will see many in the hill towns. There is a multitude of large boulders in Franconia opposite the Valley house. They cover acres of land, some of them being 20 feet long. On top of Flume mountain is a boulder 25 feet long, 15 wide, and 12 high. Near Fifield's house in Thornton, on the east side of the Pemigewasset, is a boulder averaging 30 feet in each of the three dimensions. At the south part of Rattlesnake hill, Concord, is an uncommon amount of boulders of granite, whose dispersion must have been due to the ice. Near Gilmanton Iron Works, I found boulders of quartzite precisely like that of the Coös group from Moose mountain, Hanover, to Cuba, etc., 6 by 3 by 3 feet. The distance from here to the Cuba range, north-west, is nearly 50 miles. We have preserved samples of glaciated stones taken from the drift overlying the inter-glacial clay at the Weirs and in New Hampton. A block at Weirs is 6 feet square. On the Isles of Shoals are boulders that have come from the main land. On the south part of Chocorua are granite boulders 4 feet long, and bits of porphyritic gneiss 18 inches across. On the west side of Kimball hill, in the edge of Whitefield, are boulders like the Bethlehem gneiss, perhaps brought there by the glacier described by Agassiz. There is also a moraine of the Ammonoosuc glacier, not mentioned above, below Bethlehem Hollow. In North Lisbon are bits of Albany granite, 5 inches in diameter, brought down by the glacier.

In Brookfield are numerous boulders of a siliceous limestone, such as crop out in a single ledge in Wakefield, and abundantly in Newfield, Maine. These boulders are very numerous in Newfield, and they occur on Copp's Hill, Wakefield. Observations do not demonstrate the absence of ledges of this limestone in our state, but the question is raised whether these blocks have not been transported in a south-west direction. There is a probability that, when studied carefully, a south-west distribution of boulders will be indicated for Oxford and Carroll counties.

Boulders in Sand. The Portland & Ogdensburg Railway has made considerable excavation in the surface deposits between the Notch and Fabyan's, which illustrates the nature of the till and modified drift. At the Crawford house is the first excavation, 1,320 feet long and 20 feet deep at the middle, made through one of the river moraines described on a previous page. The material came down Cascade brook from the west. It is entirely stratified, though the materials are coarse, as is shown in our heliotype illustration of it. The swell of land crowned by the Crawford house is made by this gravel deposit meeting the till of the east side of the valley.

After proceeding 864 feet beyond the gravel cut, there are excavations, mostly on the upper side of the track in an ice drift, extending for 408 feet, where the nearest point to the Saw-mill pond is reached; then there is another small cut through the same material for 216 feet. After this is a fill of 120 feet. Then follows the cut figured in our heliotype, with the title *Ice-drift over sand* printed on a railroad tie. It is a compact, unstratified mass of rubbish, the stones consisting mainly of the Montalban granites and schists common in the neighborhood, overlying layers of sand, as shown in the illustration. The material appears to conform to the surface of the ground, being just as thick in the depression as over the elevations. This earth is evidently some form of ice accumulation; it is not water-worn gravel, nor does it correspond to either of the tills. It approaches nearer to the coarse gravel at the Crawford house than to any other class of deposits known in the state, but is unlike that, in the common absence of stratification and the angularity of the fragments. Its association with the sand about to be described may intimate the presence of a mass of ice in the neighborhood in the time of local glaciation.

The rest of the cut just entered into extends for 336 feet. It is composed of sand, with some large stones in it, underlying the angular drift, as seen in the illustration. The strata dip southerly underneath the ice drift, and at the north end of the cut they dip northerly to correspond with the depression of the surface, 120 feet wide, crossed by the railroad upon an embankment. Next is another cut in the sand 264 feet long, showing boulders in it, and depressions to correspond with the surface of the ground. After an embankment 528 feet long, succeeds another cut in the sand of 384 feet length. From a point in this excavation, about 4,300 feet north of the Crawford station, was taken the heliotype illustration entitled *Boulder in sand.* The fragment may be six feet through, composed of bright granite as fresh as if uncovered yesterday, and of the same character with the adjacent ledges. Horizontal strata of sand underlie it, while the layers are slightly irregular about it, as would naturally result from the varying velocity of the current striking against the stone. The layers above are regular, and conformable with those beneath. This is therefore a clear case of a mass of stone too large to have been pushed by the current of water, nevertheless brought to this spot by some agent and dropped as readily as if it were a grain of sand. There must have been water deep enough to float ice carrying this stone upon it; and owing to a change in the equilibrium of the berg at this point, the granite fell to the bottom, and lies in a condition of

repose, not unstable like the rocks in the lower till. There may be twenty other examples of large stones of similar origin in the 1,200 feet of excavation passed through north of the ice drift mentioned. The conditions involved by the facts seem to be the presence of thick masses of ice upon the sides of Mt. Tom sliding down like glaciers, and carrying detritus, together with the existence of very much water,—possibly a glacial lake almost as high as the Crawford house,—into which the bergs loaded with stone floated, after being dissevered from their source, and dropped their burdens. The waters continuing to flow, layers of sand and other débris covered up the dropped fragments until the supply ceased. As these deposits are situated upon the surface of the ground, they belong to the close of the ice period, and must have been formed by local glaciation. If the railroad be followed to Fabyan's, three or four miles further, there will be seen a constant repetition of phenomena similar to those just described. The same is true of the excavations in the White Mountains Railroad below the White Mountain house, and between Fabyan's and Ammonoosuc. A cut through "Winding hill," near the "Base" on the latter route, shows coarse boulders, probably glaciated at the bottom, capped by stratified layers somewhat ferruginous, suggesting the lower and upper tills of other parts of the state.

The sand deposits east of Fabyan's have large stones resting upon them, obviously brought there at the same time and in a similar manner with those just described. The valley of the South Branch also exhibits fine examples of kames, which seem to have been contemporaneous with the sand, and produced by the same glacial currents.

Other examples of boulders lying in or upon sand have been mentioned, upon pages 89, 105, 107, 117, 162–163, etc. Notable instances are also just below the Glen house, the Bartlett boulder, at North Lisbon on the new Franconia road, and east of Rock Rimmon in Manchester.

SHAPES OF GLACIATED BOULDERS.

By far the most common shape of glaciated boulders is that of a rounded trapezoidal prism, whose longer sides do not vary much from parallelism to each other. One such is figured in the heliotype showing boulders from Hanover. In this the ends are rather sharper than is common. Perhaps half the thoroughly glaciated stones have such a shape. Of these the four longer sides are usually striated parallel to each other.

My attention was called to this as a typical shape by examination of certain large striated boulders. In 1856, a boulder of red sandstone was exhumed in Amherst, Mass., 6½ feet long, 5½ broad, 2¾ thick, having striæ upon the four longer sides parallel to each other.* This was described as something unusual. I found in Quebec, a few years later, similarly striated boulders somewhat larger; and in the glacier de Bossons in Chamouni, at the foot of Mt. Blanc, I noticed the same trapezoidal figures in a very large stone, 40 by 27 by 12 feet in its dimensions. It was striated on the same four sides as the others, and had the ends rough. It lay just below the ice, with its longer axis parallel to the course of the glacier. Since that time I have always observed the shape of glaciated stones, and think the majority have the same form with these that I have mentioned. Originally rough, and possibly somewhat rectangular, they have been both ground down and striated by the sliding over them of the glacial rasp, or have been themselves fastened into the foot of the ice, and ground over other stones and rocks. After miles of scouring, the largest boulders might be worn symmetrically to the size of pebbles. On scrutinizing the shapes of stones in the till, one can frequently find various stages of this process preserved. In Derry and Salem I noticed a large number of flat stones, of which only one side had been smoothed. Let the circumstances be changed so that these boulders be turned over, and the present upper rough side will be glaciated, and the whole become symmetrical. A few have several faces upon them, as if they had been fastened in the paste several times. Fig. 58 shows a glaciated stone in Moultonborough, striated in the usual way, and also by a second set *(b)* across the preceding. It is 30 inches long, 14 thick, composed of trap, and lies by the roadside upon a mass of till.

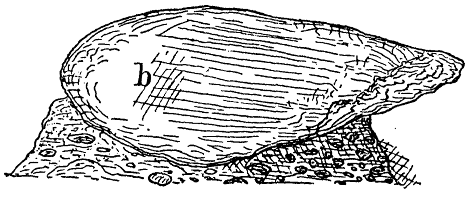


Fig. 58.—Glaciated Stone, Moultonborough.

A more interesting case has been partially preserved in the Hanover museum. About two miles north of Norwich village, Vt., on the road to Copperas hill, is a hill thirty feet high, of lower till with innumerable glaciated stones cemented by boulder clay. One of a micaceous argillite may weigh 1500 pounds, perhaps five feet in length, of the typical trapezoidal shape, except it is narrower than usual. The longer axis points a little east of south, as the stone lies in the bank. The under surface and the sides are striated parallel to the longer axis, but the upper surface bears very plain marks at right angles to those beneath. I was able to preserve only a piece of this boulder, showing the upper surface and the beginning of the lower striæ at right angles to them. The boulder proved larger than was expected, so that I could not transport it entire to Culver Hall.

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* *American Journal of Science*, ii, vol. xxii, p. 397.

A common variation in shape is the elongated narrow one, a prolate spheroid. Geikie, in his work on the Great Ice Age, figures four striated stones from Scotland, three of which clearly possess the typical shape I have mentioned, while the fourth is blunt at one end and pointed at the other,—a form also seen with us. These stones show the same features the world over. Argillaceous boulders best preserve the glaciation.

Surface Deposits at Portland, Me.

The relations of the two varieties of till to the Champlain gravels are not exhibited in any outcrops yet discovered in New Hampshire. A familiarity of long standing with the fossiliferous clays and the drift of Portland, Me., led me to think the question of relative position well shown there; and upon examination I discovered that the fossiliferous beds occupied a place midway between the two kinds of till. Numerous excavations have made the sections in the till and sands perfectly satis-

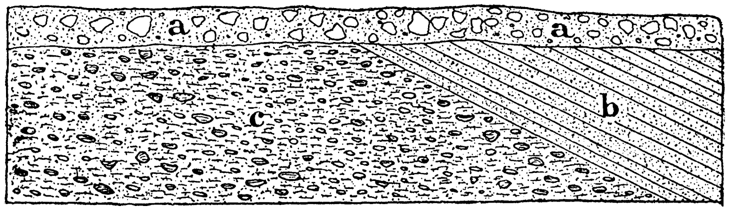

Fig. 59.—Section in Till, Portland.

a. Upper till; b. Fossiliferous Champlain beds; c. Lower till.

factory, so that the mutual relations of the three deposits, as displayed in Fig. 59, may be regarded as fixed beyond controversy. The massive beds overlie the lower till, and are covered by the upper till. These facts indicate the deposition, first, of the ferrous glaciated till; second, its submergence to at least 100 feet below the present level; third, the reädvance of the ice-sheet so as to cover the Champlain beds; fourth, the melting of the ice, and the falling down of the débris held in suspension in it. The formation of the upper till does not necessitate a submergence, as I have insisted in previous publications. That these positions may seem well sustained, I will state the most important facts observed about Portland.

The city is situated upon a promontory, or, practically, an island, with a north-east trend parallel to the coast. The island has two elevations, 150 and 160 feet above tide water, and at the remoter ends the extreme edges slope very sharply to the water's edge. The eastern elevation is Munjoy's, and the western Bramhall hill, and between the land sinks to 60 feet along the lowest ridge. These two hills consist of the two kinds of till; and each is environed by the Champlain deposits, which cover most of the lower area in the middle. These attain an elevation of about 100 feet; and the ocean must have stood a few feet higher, unless the character of the fossils in the lower clays—pelagic forms—necessitated a submergence of 300 feet. In that case, Munjoy's and Bramhall hills would have been deeply buried by the waters.

Munjoy's hill has been excavated in a multitude of places, showing an upper till, from 3 to 10 feet thick, as clearly defined and distinct from the lower deposit as at Boar's Head. Boulders from 3 to 4 feet in diameter occur upon the surface, and are of the gneissic, granitic, and schistose rocks common from four to ten miles to the north-west. Fig. 59 represents a cutting between North and Washington streets, and may be taken as a sample of excavations on that side of the ridge. Along North street for half a mile is a continuous exposure of the two kinds of till. Upon both sides is a cut 25 feet deep. The larger stones are all under or at the surface, but they are not striated. The lower deposit is compact, the stones of small size, and all glaciated and transported a greater distance than those above. I found pebbles of the White Mountain porphyries and sienites among them, indicating a carriage of 50 miles. The other hill in the west part of the city is broader, and no excavations of consequence are visible. The surface deposit is altogether that of the upper till, and identical with that on Munjoy's. The coarseness of this deposit has led to its reference to the usual glacier drift by many geologists; but I think its proper place is now found by a reference to the upper till. A few have regarded the fossiliferous deposits as of Tertiary age, because the upper till overlies them. It is very easy to see how such a mistake could be made, if the distinction between the upper and lower tills is overlooked.

An examination of the Champlain deposits shows they do not occur upon the tops of these hills, but encircle them, and in strata dipping quaquaversally outwards. Fig. 59 is chosen from a locality where Mr. C. B. Fuller found mussel shells lying in a position analogous to that assumed by the living animals. The siphon-holes above them still remained, where sand had silted into them from above. Such specimens could not have been transported by waves. A list of all the known fossiliferous localities is the following:

Along east side of Munjoy's hill for 400 yards between Eastern promenade and the Grand Trunk Railway.
Portland Company's works, St. Lawrence street.
Adams street.
Between Fore street and the custom-house.
Cove on Washington street opposite north end of race-course.
From this point to Fox street.
Between Washington and North streets.
In an old pit on Congress street above Mountfort street.
Almost anywhere north of Congress street between Alder and Anderson streets.
Congress street north of reservoir.
Old slide next canal, described by Prof. E. S. Morse.
For 200 yards at the foot of Emery street.
Knightsville,—nodules containing shells, fish, etc.; very abundantly in Deering, Woodstock, Cape Elizabeth, and islands in Casco bay.

A list of the fossils found about this city by Mr. Fuller embraces 5 vertebrates, 31 crustacea, 2 annulosa, 55 mollusca, 2 echinoderms, and 26 foraminifera,—121 species in all. Undoubtedly every one of these creatures lived at the same time in the New Hampshire waters, only a few miles distant, where the facilities for their preservation did not exist.

These animals were not exactly the same with those now living on our coast, corresponding better with those living farther north. The best writers name three different groups for the eastern American coast. The arctic fauna is at present confined to the limits of North Greenland, and about the pole at the isotherm of 0° C. This is succeeded by the Labrador or Syrtensian fauna, extending now as far south as to the mouth of the Bay of Fundy. Our present New England or Acadian fauna extends from the southern limit of the Syrtensian to Cape Cod, and also appears in several places above the lower limit of the latter. The lower British Provinces exhibit one or the other of these faunas according to the presence of the polar current or the influence of the Gulf stream.

The fauna of Portland in the Champlain period corresponded to the Syrtensian, or the colder one. It seems to have extended as far south as Gloucester or Cape Ann. The northern limit of the Acadian fauna during the same period was near Point Shirley, Winthrop, Mass. Thus the glacial cold was sufficient to bring the boreal life two and a half degrees farther south than it is found at the present day.

A list of all the Champlain fossils known to occur in New Hampshire has been given upon page 165. The whale's vertebra, cited from Somersworth, must be eliminated from the list. An inquiry into its authenticity has indicated that the specimen did not come from the locality specified upon the label.

THE GROUND MORAINE.

The common masses of drift scattered over the state are known typically as ground moraine, such as is accumulated beneath glacial ice. The Scotch word for the material is *till,* which is adopted in this report to signify the ordinary unstratified glacial accumulations. For reasons derived from the Manchester exposures, this term is preferred to a common one of *boulder clay.* The sub-divisions of it have been defined upon page 9. We accept the theory there stated, that the lower till is the proper ground moraine, and the upper ferruginous division is derived from the melting of the ice-sheet.

Recent studies reveal the existence of curious lenticular-shaped mounds of till, some of quite large dimensions. These proved so interesting that Mr. Upham was asked to devote a season in studying them.

He will shortly present the results of this examination, and color upon the map of Surface Geology their geographical positions. No feature of our drift moraines is so striking as this, and it is singular that previous authors have almost universally overlooked or misunderstood it.

The question has been put to us, As New Hampshire has not been submerged since the Helderberg period, and there may have been other periods of cold besides the one called *par excellence* the glacial drift, why do we not find moraine accumulations of the earlier ones? I think we have abundant evidence of a Triassic glacier in Massachusetts, formed of materials partly derived from New Hampshire. The stones of the Mt. Mettawampe conglomerate are too coarse to have been moved by water alone, and the stones have a glaciated appearance. As there seem to be no rocks in our state analogous to the Triassic conglomerates, we may say, with assurance, that if any glaciation occurred previous to the post-tertiary, it could not have antedated the New Red Sandstone. It seems probable that Tertiary glaciated beds would be characterized by features quickly discernible, and not easily confounded with anything else earlier or later.

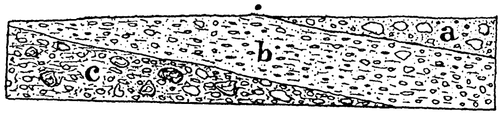

Fig. 60.—Section in Till, Lyndeborough.

a. Upper till; b. Lower till; c. Hardpan.

But certain beds are brought to our notice, which seem to antedate the lower till. The best known is represented in Fig. 60. A railroad cut in South Lyndeborough, two miles west of the station, exhibits three layers in the till. The top is the familiar loose ferruginous earth, such as universally covers the ground-moraine. Next, *b*, is a good example of the lower till, full of glaciated pebbles, porphyritic and granitic gneisses, mica schist, etc., 5 feet, and in one case 6 feet long. The laminated appearance arising from compression is clearly defined. Beneath this is a coarser mass, reaching to the bottom of the cut, so very compact that a pick had no effect when struck into it by the workmen; only gunpowder or a stronger explosive could excavate it, and it was necessary that the holes should be bored horizontally near the surface to become effectual in removing the earth. There is nothing visible in the earth itself different from the lower till above it, save that the components average coarser. This hardpan is certainly prior in age to the lower till; but that circumstance may not compel us to call it Tertiary. If length of time is requisite for the induration of till, this hardpan should be much older than the common moraine. There is nothing of significance in the shape of this earth heap. It is not as conspicuous as a small lenticular hill. After the access of air to the lower deposit, its great induration disappears. When it is well exposed to rain, water mixes with it, making a compound that will flow readily down a slope.

A case similar to this is in Pittsfield, midway between Webster's mill and the village. The railroad excavators had the same experiences that have been narrated for Lyndeborough. Gov. Prescott informs me that similar experiences befell persons endeavoring to excavate the earth for a well near his residence in Epping; and recently I found the same story told of drift in Amherst, Mass., and Hartford, Conn. The examples may multiply, and eventually furnish us the answer to our question as to the peculiarities of their origin.

Drift in North Conway.

As an example of the aspect of the difference between the ordinary till and the modified drift, I would refer to the accompanying heliotype, illustrative of these two deposits in North Conway where the road crosses Artists' Falls brook, near the Macmillan hotel. To render the sand more distinct, a faint brown color is employed to show its limits. It is about 10 feet thick, forming about one fifth part of the exposure. There are boulders in the till here about a yard in diameter. The sand of North Conway is usually widespread, but very thin. Quite a large mass of it, as long as a small lenticular moraine, occurs just to the south of the stream opposite the hotel. This is the position from which the fine view of Mt. Pequawket, employed for the frontispiece of Volume II, was taken.

Plant Relics of the Glacial Period. Full descriptions of the Hudson's Bay and Greenland floras now existing in the White Mountains have been presented in Volume I, pp. 392 and 568. No better argument to show that an arctic climate once existed in New Hampshire than the presence of these plants, as well as the corresponding insects described in the same volume, Chapter XII, can be adduced. They also imply the correctness of the glacial instead of the iceberg theory of the drift, and also that the cold conditions spread themselves gradually over the continent, disappearing slowly also.

THE DISTRIBUTION OF THE TILL.

BY WARREN UPHAM.

Before the glacial period, the rocks of New Hampshire had been through long ages subjected to the ordinary disintegrating agencies of rain and frost. The loose material derived from this source was doubtless spread with considerable evenness over the surface, collecting to the greatest depth in valleys, while on ridges or hill-tops it would be thin or entirely washed away. Except where it had been transported by streams and consequently formed stratified deposits, the only fragments of rock held in this mass would be from underlying or adjoining rocks.

Through this time temperate or tropical climates generally prevailed; but it also seems probable, if the causes of the glacial period have been rightly made to depend upon great eccentricity in the earth's orbit, that these genial conditions were at times interrupted by prolonged cold and the accumulation of slowly-moving ice-fields similar to the immense glaciers of Greenland and antarctic lands. Scarcely any hint, however, has been obtained in a full survey of our territory respecting these events, all records of which appear to have been erased by the last great ice-sheet, which pushed from the north and north-west straight forward over all the hills and mountains of New England, terminating beyond our coast-line. The beds which had been derived from long-continued decomposition of the ledges or gathered by previous glacial action, together with the thick fluviatile deposits that probably occupied the valleys, were ploughed up by this ice-sheet, and thoroughly kneaded with each other. Very large amounts of detritus were also added from erosion of the rock-surface. Fragments of all sizes and in great profusion were loosened and wrenched away, while the ledges were everywhere worn and striated by boulders and pebbles which were rolled and dragged along under the vast weight of ice, breaking up and grinding themselves and the underlying rock into gravel, sand, and even the finest clay.

At the end of the glacial period, the material which had been thus gathered, mingled and swept along by the moving ice, was left in three different classes of deposits, namely, modified drift, upper till, and lower till. The first and second of these appear to have been held in the body of the ice-sheet, principally in its lower portion. At its final melting, it has been shown that the modified drift was swept into the valleys, while the upper till, which escaped this erosion, fell loosely upon the surface, forming an unstratified, confused mass of boulders, gravel, and sand.

The characteristics of this upper division of the unmodified glacial drift are,—the large size of its boulders, which are usually abundant, being often from five to ten, and sometimes twenty or thirty feet in diameter; the angular form of these blocks, as also of smaller fragments, which have seldom been worn or rounded except by the weather; the occurrence of much of its iron in the form of sesquioxide, giving a yellowish or reddish color; and the comparative looseness of the whole deposit. Its thickness is quite variable, being commonly one to five feet, but sometimes reaching to twenty feet or more. This upper till generally forms the surface throughout the state, the only exceptions being tracts of valley or lowland, where it is covered by beds of modified drift, and frequent small areas, varying from a few square rods to several acres, or sometimes, especially upon mountains, perhaps hundreds of acres in extent, where scarcely any superficial material rests upon the ledges.

The lower till is distinguished by its smaller rock-fragments, which are commonly less than two feet in diameter, and often consist of pebbles not exceeding half this size, though occasionally it also contains large boulders; by the glaciated form of many of these stones, which are frequently marked with striæ; by the usually clayey detritus, in which they are held; by its darker and frequently bluish color, due to the imperfectly oxidized state of its iron; and by its very hard and compact structure without stratification, boulders, pebbles, sand, and clay being indiscriminately mixed, but at the same time showing traces of lamination, or perhaps cleavage, in planes parallel to the surface, usually noticeable wherever a section has been for a short time exposed to the weather. All these features indicate that this division of the drift was accumulated beneath the ice as its ground-moraine. Rough and angular boulders, pushed along under the glacial sheet, were worn to small size, having their sides planed off and striated; and in the same manner gravel and sand were pulverized to clay. Secluded from air and water, the iron remained in the protoxide combinations which it had in the solid rocks. Analyses of upper and lower till from Alton, by Mr. Hawes, show the following percentages:

	Upper till.	Lower till.
Iron protoxide,	1.42	1.75
Iron sesquioxide,	1.56	0.006

These samples were taken within a foot of each other, close to the line of contact of the two deposits. The hardness of the lower till, which requires it to be loosened by a pick before it can be shovelled, making its excavation cost two to four times as much as that of the upper till, appears to have resulted from the immense pressure of the ice. The imperfect lamination, which has been commonly observed in exposures of the lower till in New Hampshire, may be due to the same cause, but more probably to its accumulation by a gradual increase of depth. It seems to show that the ice in its passage added new material to the surface of its ground-moraine, which generally lay undisturbed below.

The distribution of the lower till is quite irregular, being much less uniform than that of the upper till. It occurs in all parts of the state, but is often wanting, and probably does not occupy more than half of its area. It is most commonly spread in flattened sheets, which may be nearly level, or inclined upon the flanks of hills or mountains. In the northern part of the state and among the White Mountains, the unmodified glacial drift often forms the slopes or rests upon the tops of the highest ridges. Its distribution seems to have no reference to the altitude or configuration of the land. The summits on the highland boundary between New Hampshire and the province of Quebec, as near Lake Magalloway and Mt. Prospect, near Third lake, are described by Mr. Huntington as principally covered with till. The same is true of the top of Moosilauke, 4811 feet above the sea. Striæ show that the ice-sheet moved over these elevations from lower areas at the north-west, where a large part of its drift was probably collected, to be carried forward and deposited at a higher level. The summit of Mt. Washington is covered by débris (described on p. 205), which seems to correspond to the upper and lower divisions of the till.

Lenticular Hills. In the south part of the state, the glacial drift is probably not more abundant than among the mountains, but becomes more interesting because of its accumulation in massive, rounded hills, principally composed of lower till, which form the most prominent elevations near our coast, in Essex county, Mass., and southward to Boston.*

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* These remarkable deposits of glacial drift have been described in the *Proceedings of the Boston Society of*

A special exploration has shown that these hills are also finely developed, being more numerous but somewhat less massive, in Merrimack, Hillsborough, and Cheshire counties, and in many parts of central Massachusetts. They vary in size from a few hundred feet to a third or a half mile in length, with usually about half or two thirds as great width. Their height, corresponding to their area, varies from forty or fifty feet to one hundred and fifty or two hundred feet. But whatever may be the size of these hills, they are singularly alike in outline and form, usually having steep sides, with gently-sloping, rounded tops, and presenting a very smooth and regular contour. From this resemblance in shape to an elliptical convex lens, Prof. Hitchcock has called them *lenticular hills*, to distinguish these deposits of glacial drift from its broadly flattened or undulating sheets, which are common throughout the state.

The lenticular hills have a well defined trend, which shows a very notable parallelism with the striation of the rocks. Next to the coast it is prevailingly north-west to south-east, while farther inland it has very few exceptions from a nearly north and south course. In addition to the occurrence of the glacial drift in lenticular hills, it is frequently amassed in slopes of similar lenticular form. These have their position almost invariably upon either the south or north side of the ledgy hills against which they rest, showing a considerable deflection towards the south-east and north-west in the east part of the state. It cannot be doubted that the trend of the lenticular hills, and the direction taken by these slopes, have been determined by the glacial current, which produced the striæ with which they are parallel.

Slopes of till accumulated on the lee side of projecting ledges have been described by European glacialists, the hill and the detritus sheltered behind it being commonly known as "crag and tail." The greater portion of these slopes which have been noted in New Hampshire are sheltered in this way; but about a third of them lie upon the northern side, which was exposed to the ice-current. In rare cases these slopes have gathered upon both north and south sides alike, blending together and assuming the form of a lenticular hill of glacial drift, but having exposures of ledge at the top. In many true lenticular hills outcrops of solid

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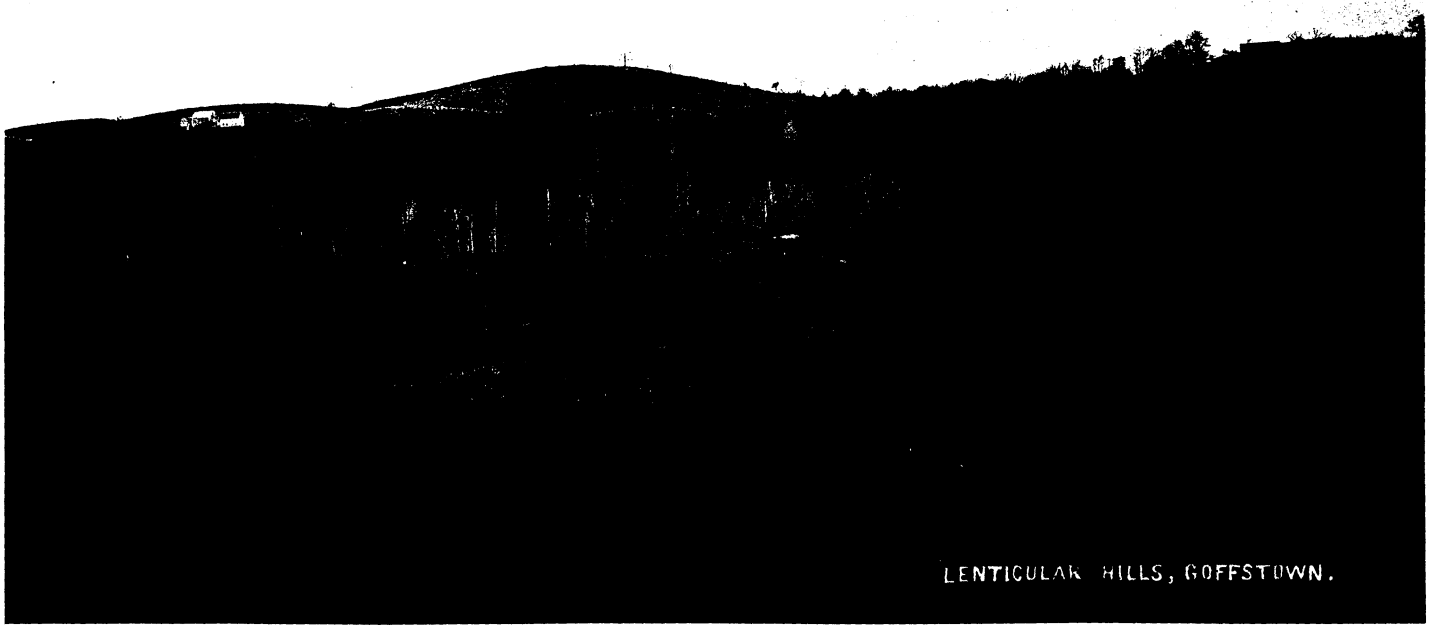
Natural History by Prof. N. S. Shaler (vol. xiii, pp. 196–203), and by Prof. C. H. Hitchcock (vol. xix, pp. 63–67). They seem to resemble the "drums" or "sowbacks" of the till in Scotland, mentioned in Geikie's *Great Ice Age*.



LENTICULAR HILLS, GOFFSTOWN.

rock occur near their base, and evidently form a pedestal capped by a rounded mass of till fifty to one hundred feet in depth.

These hills of glacial drift may be recognized by their smoothed surfaces, overspread, indeed, with the large boulders which are common in the upper till, but moulded in gracefully curved outlines unbroken by jutting ledges, which give to all our other hills a more or less angular and abruptly undulating surface. Our elevations of rock are commonly in irregular groups or ridges, with outlying spurs, and, except in the south-east part of the state, they are far more massive and prominent than the lenticular hills. These accumulations of till are further distinguished by their fertile soil, well adapted for pasturage or cultivation, which frequently makes them the most valuable land in the districts where they occur. On this account, they have almost invariably been cleared, while the more rugged, ledgy hills remain covered with woods.

During exploration for mapping the lenticular hills, notes were also taken of sections in the glacial drift, shown by excavations for building and repairing roads, or for wells. These observations are presented in the following table, which shows depths of upper till varying from one to seventeen feet, resting, in all but five instances, directly upon the lower till, their separation being a definite line. It will be seen that thin layers of sand are occasionally found in both these deposits, appearing to be most frequent in the lower till, where they are sometimes inclined or nearly vertical. In most cases where thick beds of gravel, sand, or clay occur in the glacial drift, their position is between the upper and lower till. A few examples appear in the annexed table, and others are described on pages 108, 131, 137, 159, and 163 of this volume. It will be seen, also, from this table, that thick stratified deposits are sometimes found in or beneath the lower till. Wells in this compact boulder-clay, which is usually impervious to water, often encounter springs issuing from these beds or from thin seams or layers of sand, which therefore must extend a considerable distance. In most of the sections noted, the base of the boulder-clay was not reached. Nearly half of these sections are upon lenticular hills or slopes, which are thus shown to consist of a thin stratum of upper till at the surface, while the larger central portion is a massive accumulation of ground-moraine or lower till.

SECTIONS OF THE GLACIAL DRIFT IN NEW HAMPSHIRE.

LOCALITIES.	Thickness in feet.			REMARKS.
	Upper Till.	Lower Till		
Ashland,—2 miles east of village	4	25		*a.* Three wells, nearly alike in material, about 60 feet above the base of the slope. The lower till was here underlain by dark gray, loose gravel, "like that of a stream," extending 5 feet (not penetrated). The largest pebbles of this gravel were 3 or 4 inches in diameter.
Sandwich,—Notch road	2	3		
Lenticular slope at south town line	3	27		
Moultonborough,—several places	2	3-5		
Tuftonborough,—Fernald's hill, lenticular slope, resting against ledge at south-east	3	10-15	*a.*	
Wolfeborough,—lenticular slope, 2 miles N. of village	2-4	20-30	*b.*	*b.* Two wells. Lower till underlain by a water-bearing stratum of sand or fine gravel.
Near Cotton Valley station	4	10		
Ossipee,—Fogg's ridge, lenticular hill	3	17		
Alton,—½ mile west of Alton Bay	2	3	*c.*	*c.* Specimens analyzed.
Gilmanton,—several places	1-2	10		
Sanbornton,—west of Hopkinson hill	2	3		
Tilton,—2 miles north of village	2	5		
Rochester,—top of Haven hill, lenticular	3	37		
At Walter S. Hussey's, on south slope of a lenticular hill	3	20		
At J. E. Chesley's, ½ mile south-east from last, on north slope of a lenticular hill	5	10		
Strafford,—2 miles south-east of Bow lake	1½	3		
Pittsfield,—Tilton hill, lenticular slope, resting againt ledge at south-east	1-2	20		
Loudon,—1 mile east of Hot Hole pond	3	5	*d.*	
Lenticular slope 1 mile south-west of Clough pond	5	15		*d.* Very irregular in contour.
Canterbury,—¼ mile east of centre	1½	4		
1 mile south-west of centre	2-5	10	*d.*	
Concord,—1 mile north of East Concord	2	8		
Road to St. Paul's School	2	3		
South-west side of Rattlesnake hill	1½	3		
Hopkinton,—lenticular slopes on south side of Beech hill, at A. P. Ober's	4	36	*e.*	*e.* Lower till contains occasional layers of sand a few inches thick.
" " C. H. & H. Merrill's	1½	18	*e.*	
" " S. Johnson's	2	32		
In south-west part of town	1-2	5		
Warner,—Pumpkin hill, lenticular in form, with small exposure of ledge at top	2	20		
Andover,—at west town line	2	3		*f.* Lower till underlain by a water-bearing stratum of gravel.
New London,—at Institution, upon a broad lenticular hill	2	43	*f.*	*g.* Lower till showed two or three seams of sand, 1-5 inches wide; it is underlain by a softer clayey stratum, 1 foot thick, resting on ledge.
¼ mile south-east from last	1½	26	*g.*	
Washington,—hillside south-east of Millen pond	2	18		
Sullivan, Harrisville, and Dublin,—several places	1½-3	5		
Swanzey,—1½ miles south of Wilson's pond.	2½	3		
New Ipswich,—north-west part	1½	5		
1½ miles north-east of village, at north foot of a lenticular hill	1½	4	*h.*	*h.* Lower till underlain by 5 feet of stratified sand, which continues below the excavation.
Greenfield,—½ mile east of Cragin pond, on lenticular slope, resting against ledge at north	2½	20		
½ mile farther east, at north-west foot of Lyndeborough mountain	1½	26		*i.* Lower till contains occasional layers of sand, 1-2 inches thick.
Bennington,—east part, on south end of a lenticular hill	1½	20	*i.*	
Wilton,—north-west part, at county farm	1½	15		*j.* Upper till contains layers of sand, 3-6 inches thick.
⅛ mile north-east of East Wilton	12	10	*j.*	
⅛ mile west of East Wilton	15	....	*k.*	
New Boston, at S. Dodge's, on south slope of a lenticular hill	6	10	*l.*	*k.* Upper till contains layers of sand, and is underlain by 10 feet of stratified clayey sand, which extends below the excavation.
Beard's hill, lenticular, on its south slope.	5	15		
½ mile east of last	2	4		
⅓ mile north of village, on east side of a lenticular hill	3	17	*m.*	*l.* Two wells. The upper and lower till were here separated by a stratum, 5 feet in thickness, of very compact ferruginous earth, free from pebbles. The lower till contains occasional thin layers of sand.
Cochran's hill, lenticular, on its north slope	2	35		
At the south-east foot of Wason hill	9	6		
Amherst,—lenticular mass upon Chestnut hill, ⅛ mile east of O. Carter's	6	15		
Goffstown,—on south slope of a lenticular hill, 2 miles north-west from Centre	4	18	*n.*	*m.* A nearly vertical seam of ferruginous sand, 1-1½ feet wide and 10 feet long, was exposed in this lower till.
1 mile north of last	2	3		
Stratham,—top of lenticular hill, 1 mile west of Rollins hill	3	40		

Kingston,—lenticular mass, on south-west side of Great hill	5	25		*n.* Two or three seams of sand, inclined 45°, 3–6 inches wide and several feet long, occur in the lower till, which is underlain by a stratum of black clayey sand 1 foot or more in thickness.
East Kingston,—lenticular mass, on south-east side of Great hill	3	60		
Kensington,—Moulton ridge, lenticular hill, at top	10	30		
1 mile south of last	17	5	*o.*	*o.* Upper and lower till separated by a layer of sand 4 inches thick.
Top of lenticular hill, south of Muddy pond	5	15		
North-west slope of same hill	13	15	*p.*	*p.* Upper and lower till separated by 6 inches of waterworn gravel.
South Hampton,—north-west village	6	10		

The average thickness of the upper till, obtained by taking the mean of these observations, is three feet and nine inches. If we subtract one tenth of this, due allowance will probably be made for areas that are destitute of this deposit, leaving three and one third feet, which would thus appear to be approximately the mean depth of the upper till, if it were spread in a sheet of uniform thickness over the entire state.

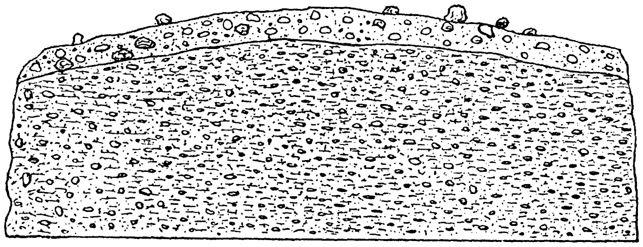


Fig. 61.—SECTION OF GLACIAL DRIFT, TWO MILES EAST OF ASHLAND, illustrating the usual mode of occurrence of the upper and lower till throughout the state.

Thickness of the upper till, 4 feet; of the lower till, 25 feet. The most abundant boulders in the former were porphyritic gneiss; in the latter, Montalban.

The lower till, however, does not appear to have any development upon half of this territory, being accumulated in patches, sheets, and lenticular masses, while over adjoining areas of equal extent the ledges are exposed or covered only by the upper till. Very few of these sections show the whole thickness of the lower till; and its depth in the lenticular hills affords no basis from which to judge of its other deposits. It is impossible, therefore, to arrive at an estimate, as before, from this table. If we still wish to form some conclusion respecting the entire mass of the ground-moraine, it will be well first to consider the lenticular hills and slopes, of which about eight hundred and sixty have been noted in southern New Hampshire. The portions of these which consist of lower till may average equal to a depth for each of fifty feet upon an area of one tenth of a square mile. This indicates that the lower till, accumulated in such masses, would form a layer perhaps six inches thick, if evenly spread over the whole state. These hills and slopes are only found, however, upon small portions of this area, and for the districts of their greatest abundance in Cheshire and Hillsborough counties, as in portions of Walpole, Chesterfield, Dublin, Jaffrey, Rindge, New Ipswich, Temple, Wilton, New Boston, and Goffstown, would probably yield continuous sheets five to ten feet in thickness; while in Kensington and South Hampton, which represent their greater development near the coast, they may be equivalent to a uniform depth of thirty or forty feet. The average thickness of the lower till in flattened deposits, found throughout the state, can only be conjectured. It varies in depth from a few feet, as is most common, to twenty, thirty, or perhaps sometimes fifty feet. Our impression of its aggregate amount, including the lenticular hills and slopes, is nearly the same as the estimate derived from the foregoing table for the upper till. The modified drift, described in the first chapter of this volume, must also be nearly the same in its total mass.

The whole depth of the drift in New Hampshire, if uniformly distributed, would therefore be something like ten feet, of which nearly equal portions occur in each of its three divisions of modified drift, upper till, and lower till or ground-moraine. In this connection, we must bear in mind that a considerable part of the drift gathered by the ice-sheet from our territory was carried beyond our coast-line and deposited in submarine banks.

The distribution of the till has been carefully noted throughout that part of the state which lies south of Grafton county and the White Mountains. Its most interesting deposits are the lenticular hills and slopes. These have been represented in the atlas, on the map that shows the courses of striæ. It will be seen that their longer axes agree in direction with these tracings of the ice-current. The same map also shows lines of contour, with which the irregular distribution of the lenticular hills may be readily compared. It would be expected that their abundance or absence must be determined, or at least influenced, by the very irregular outlines of the surface; but we have been unable to discover this relation or dependence, if any exists. In the northern portion of the area explored, the till is common in patches and extended sheets, but forms only few and scattered lenticular hills or slopes. Farther south, these remarkable accumulations occur quite abundantly upon three belts of our territory, one of which extends through the west part of Cheshire county; another, from Goffstown and Weare south-west to New Ipswich and Rindge; and the third, through eastern Rockingham county. The general features of these lenticular deposits of till, which have been already given, apply to them in all parts of the state where they have been found, and also in north-eastern and central Massachusetts, leaving little that needs to be particularly mentioned, except the localities of their most conspicuous or noteworthy occurrence.

Sullivan County. The glacial drift does not form many prominently rounded masses in this part of the state. A lenticular slope of till, resting against higher ledges at the north, was observed two miles west of Meriden on the north side of Blow-me-down brook. Even such deposits are rare in most of the towns of this county. Southward, lenticular accumulations of till were noted on both sides of Sugar river one to two miles east of Claremont. The first of these on the north side of the river falls off abruptly at its south-east end, having evidently been undermined by this stream, which now flows thirty rods distant, separated by a low flood-plain. No lenticular masses were seen in Newport, but considerable till is spread out in flattened sheets. For fully a mile in the west part of this town, beginning a little below Kelleyville, such a deposit has been undermined by Sugar river, and forms a continuous bluff on its north side 75 to 100 feet high. The slope southward from Acworth centre to Cold river, amounting to about 500 feet in two miles, is principally covered with till, much of which is massed in rounded hummocks with several lenticular hills near the bottom. At the northward bend of the river, a half mile west of South Acworth, it forms a bluff 100 feet high The ascent on the south side of the valley towards Alstead is also marked by frequent patches of till.

Cheshire County. In the west and south-east parts of Cheshire county the lenticular hills are finely developed, but they are almost entirely wanting over an intervening area which averages ten miles in width. At East Alstead, and for a mile to the north and east, the surface is mostly till, which occurs in broad swells, resembling lenticular accumulations. Well marked examples of "crag and tail" occur one mile north-east and a mile and a half east-north-east from this village, the latter example being in the edge of Marlow. Many fine lenticular hills occur in the south part of Walpole, scattered among more prominent hills of ledge. At a mile and a half south-east from the village, the road which leads north from school-house No. 4 climbs a rounded slope of till nearly

200 feet in height. From its top two prominent hills of this class are seen within a third of a mile on the west. Another fine example was noted about a mile south from these; two more occur a mile west from the last; and several were seen in the south-east part of the town, one lying a short distance north-west from school-house No. 13, and others within a mile to the west and south.

The valley of Thompson brook, in the south-west corner of Alstead and north part of Surry, is bordered by large deposits of till, which at several places have a well defined lenticular form. These hills are also well shown along the Ashuelot valley in Gilsum. In Westmoreland they are numerous along the route of the Cheshire Railroad, occurring close north of East Westmoreland depot, at one mile west and south-west, and for one mile to the south. No typical lenticular hills were noticed near Westmoreland village, but similar masses of till rest against a ledgy hill one mile south-west; and at a mile and a half south a broad sheet of it forms the north slope of Pistareen mountain. These hills are very finely shown in Chesterfield, as many as fifty distinct lenticular accumulations being noted. They abound from Factory village west to Connecticut river, being especially numerous and massive within a circuit of one mile about Chesterfield centre. Only inconspicuous examples occur in Hinsdale; but Winchester has about a dozen well defined and prominent lenticular hills within four miles north from Ashuelot and Winchester villages. These constitute an isolated group, surrounded on all sides for three or four miles by irregular ledgy hills with no considerable accumulations of till. In each of these towns, other areas adjoining those which we have described are destitute of these deposits.

The central portion of this county, which has only very rare lenticular hills, comprises the towns of Marlow, Stoddard, Sullivan, Roxbury, Keene, Swanzey, Troy, Richmond, and Fitzwilliam. In Nelson, these hills are found near the village. Several good examples, 50 to 75 or 100 feet deep, occur within a half mile to the south-east and within a mile and a half to the west. In Harrisville and Marlborough a few lenticular hills are noted; but the greater part of these towns shows no trace of them.

Their best display in this county is at the south-east, in Dublin, Jaffrey, and Rindge. On the north side of Monadnock mountain they are finely developed, four very prominent examples occurring about two miles north-west from Monadnock lake, which is also bordered by small but typical lenticular hills on its north-west side. Their trend here is uniformly from north-west to south-east, or nearly so, while in other parts of this county it is almost always approximately from north to south. This divergence of 45° from the usual course was due to deflection of the ice-current, for the striæ of this vicinity show the same eastward deviation. Between Dublin village and Thorndike pond numerous lenticular accumulations occur; but many of them are not true hills, since they rest against ledges at the north. The east half of Jaffrey and nearly the entire township of Rindge are well filled with the lenticular hills, which vary from 50 to 150 feet in depth, but scarcely any of them have received special names. Their fertility has caused them to be cleared, and their smoothed fields of pasturage or mowing contrast notably with the ledgy hills of similar height but very irregular outlines, which abound in the next fifteen miles to the west.

Carroll County. The lenticular accumulations of till which have been observed east of Lake Winnipiseogee lie most frequently on the north-west side of hills, which was struck by the full force of the ice-current. The hill upon which Sandwich Lower Corner is built may serve as an example. The north side of this hill is a smooth lenticular slope of till, but ledge appears at its top and on its south side. Fernald's hill in Tuftonborough, a mile east of Melvin Village, also has a very regular north and north-west slope of till. A bed of stratified gravel and sand occurs in the lower till of this deposit, as shown by wells at Mr. Calvin Fernald's, described on page 290. The highest point of this hill is ledge, which forms all its south-east side, being in many places precipitous. A similar mass of lower till, with modified drift beneath or enclosed in it, lies on the north-west side of a hill two miles north-east of Wolfeborough village. Pray hill, north of Pine River pond in Wakefield, has a fine north-west slope of till, while its south-east slope is ledge. Fogg's Ridge, one mile south of Pocket hill in Ossipee, is the only true lenticular hill seen in Carroll county. This is a typical example, showing no ledges for 100 feet below its highest point. Its whole north-west and north slopes appear to be composed of till; on the south and south-east, ledges form the base of the hill, extending half way to its top. Its trend, like that of the slopes of till, is approximately north-west to south-east.

Belknap County. The till south and west of Lake Winnipiseogee is sometimes accumulated deeply on the north-west slopes of hills, as in Carroll county, but more commonly it is massed on the south-east or sheltered side. Prospect hill in Alton, and Ayers hill in the edge of Barnstead, four miles farther west, are fine examples of "crag and tail," the till lying only upon their south-east sides, having, in the first case, a very straight slope, and in the latter a rounded, lenticular form. Similar masses of till rest upon the south and south-east sides of Hall's hill, one mile north-east of Gilmanton Iron Works. Several small lenticular hills occur near Half Moon pond, which is crossed by the line between Alton and Barnstead; others were noted five miles farther south, near Clark's corner; and a fine example lies three fourths of a mile south-east of Lower Gilmanton. Far the greater part of these townships, however, are destitute of any such deposits; and in the remainder of the county, towards the north-west, lenticular hills and slopes are still more rare.

Merrimack County. The lenticular accumulations of till are well shown in several of the towns of this county. They are most numerous from Pittsfield westward to the Merrimack river. Farther west, typical hills of this class are very rare; but we occasionally find massive lenticular slopes, or broad, flattened swells, of till. The north, west, and south-east portions of this county have scarcely any examples of these deposits.

In Pittsfield, the north-west slope of Tilton hill, two miles east of the village, consists of three rounded masses of till, but ledges form its top and east side. Much glacial drift is accumulated west of the Suncook in this town and the north part of Chichester, forming lenticular hills, of which Perkins's, Prospect, Jenness, Leavitt, and Brown's hills are good examples. Two of these hills occur in Loudon north of Rollins pond; three more west of Crooked pond, near a saw-mill; and four were noted near together south-east of Clough pond. Others are scattered here and there through these towns and the south half of Canterbury. The most elevated of these bunches of till lie on the north-east slope of Garvin's hill in Chichester, near its top, and similarly on Oak hill in Loudon, both of which are principally ledge. For a third of a mile next above Webster's mills in Chichester, the Suncook river has cut its channel fully 75 feet deep through an accumulation of till, which appears to have rested against a ledgy hill on the south-east. This till forms bluffs that rise very steeply from the river on its north-west side. The finest development of lenticular hills seen in this county is in Concord, north-east of Snow pond, where a group of seven or eight is included within half a mile square. At a mile and a half to the north-west, another example with a double summit is crossed by the north line of this township.

West of the Merrimack river, Horse hill in the north-west corner of Concord, and several smaller rounded masses at its south-east foot; Beech hill, at the east line of Hopkinton, at least on its slopes both to the north and south; the massive north slope of Putney hill, well seen from Contoocookville; Gage's hill, one mile west of Hopkinton village; several small accumulations in Dunbarton; and Gove's hill, north of Gove's pond in Henniker, belong to this class. In Webster, till forms deep accumulations sloping to the north, at Corser Hill village; west of Long pond; and on the north side of Little's hill. Glitten's hill in this town, and Pumpkin and Burnt hills in Warner, are very massive hills of typical lenticular form. They have outcropping ledges at their tops, while their slopes on all sides are composed of till. In Salisbury till forms the south-east slope of Lovering's hill, and the gentle swells upon which the south and central villages are built. In Andover it is prominently massed in southward slopes west of Highland lake. Its most notable accumulation in the west part of this county is at New London village, where it forms a broad rounded swell nearly a mile long. The trend of these deposits in Merrimack county is generally north-west to south-east, varying in Canterbury, the west part of Loudon, the north-east part of Concord, and in Dunbarton to a course more nearly north and south.

Hillsborough County. The north-west and south-east portions of this county are nearly or quite destitute of any lenticular masses of glacial drift. They are, however, sprinkled very abundantly over a central area ten to fifteen miles wide, which extends across the county from north-east to south-west, being connected beyond its limits with the conspicuous development of these hills already described in Dublin, Jaffrey, and Rindge.

Beginning at the north-east, we find a very remarkable group of lenticular hills, about twenty in number, north of the principal village in Goffstown. Two prominent examples occur a mile east from these, but no others were observed in this whole township. Five miles to the west these hills are again well displayed in the south part of Weare. The massive south-east slope of Dearborn's hill, and the top of Chevy's hill, which lies north-west of Clinton Grove, are also till. In the latter case it forms a rounded mass crowning a high ledgy hill, while scarcely any other lenticular accumulations are to be seen for miles around. Several of these hills and slopes occur in Deering, the most massive being on the east side of Wolf hill, and a southward slope from the hill-top west of Chase pond.

Three or four prominent lenticular hills were found in the edge of Bennington and north-west corner of Francestown, at the north side of Crotched mountain. Others lie in the east part of Francestown, north of Haunted pond. New Boston, except at its east side, is well dotted with lenticular hills, of which Beard's, Clark's, and Cochran hills, one close north of Mr. Solomon Dodge's house, two or three others within a mile to the north-west, one north of the first saw-mill below the village, others north and south-west of Cochran pond, a mile south of the village, and one less than a mile north-east of Joe English hill, are typical examples. Bedford has a few of these hills, the finest of which, a mile north-east of the village, is well seen from Manchester. In Amherst the south slope of Walnut hill is till, which also forms three lenticular hills one to two miles north-west, and several rounded masses on the south side and near the top of Chestnut hill. Prospect hill in Mont Vernon, and several southward slopes south and south-west of the village, belong in the same class.

These hills are absent from the west part of Mont Vernon, most of Lyndeborough, and the middle of Francestown; but in the east part of Greenfield they are finely developed. Two miles north-east of Russell's crossing, till lies in rounded masses on the north-west slope of Lyndeborough mountain. It also forms a smooth area of several acres near its south-west summit, and is spread in extensive sheets on its south-east side.

In Wilton, Temple, Greenville, and New Ipswich, the lenticular hills are abundant. Fine examples occur in the edge of Milford, two thirds of a mile east of Wilton depot; upon Perham hill, in the north-east corner of Wilton; a mile to the north-west in the edge of Lyndeborough; several in the north-west and others in the south-west part of Wilton; four within one mile north-east of Temple village, known as Follett, Walton, Howard, and Wilson hills; Nobby hill in Mason, one mile south of the village; Bellows and Campbell hills in Greenville, and another north-east of the depot; Jefts hill in New Ipswich, one mile west of Greenville, with others close south-west and one half to one and a half miles north-west; several one mile south and south-west of New Ipswich village; and three on the west side of Barrett mountain.

A few hills of this class are found in Peterborough, being most numerous about Cunningham pond; also in Sharon, which has near its south-west corner one of the finest examples seen in New Hampshire. The trend of these hills and slopes throughout this county is almost invariably towards the south, or ten to twenty degrees east of south.

Strafford County. No lenticular hills or slopes were found in the north part of this county. Rounded masses of till occur at several places on the south-east side of the Blue hills, south-east of Merrill's corner, and in prominent ridges near Strafford corner and centre. In Rochester five lenticular hills were noted, the finest of them being Hayes hill, now owned by Walter S. Hussey. This rises with a very regularly rounded outline 150 feet above the lowland or valleys which surround it on every side. Another of similar height, but less typical in form, lies one mile south-east, near Gonic village. Two of these in Rochester occur east of the Cochecho, being Haven hill crossed by the road to Great Falls, and Gonic hill a half mile south. The former is less steep and prominent than usual, but was shown by a well at its top to be composed of glacial drift at least forty feet deep.

Green hill in Barrington is principally till in three lenticular masses, but ledge occurs at its north-west summit. Dover has two prominent lenticular hills, neither of them typical in form. Long hill represents one extreme, being more elongated than usual, with the nearly north-west to south-east trend which prevails in this county; and Garrison hill, which rises steeply about 150 feet, is at the opposite extreme, being nearly round. Farther south, the only lenticular accumulation of till seen in this county is Wednesday hill in Lee. This is a good example of these hills, rising 75 feet above the land on all sides. Its nearest neighbors of the same class are Bald and Grapevine hills in Newmarket, five miles distant.

The towns of Maine which border this county on the south-east similarly contain scattered lenticular hills, of which Butler's hill, close east of South Berwick, and Third and Frost hills in Eliot, are very fine and prominent examples.

Rockingham County. Deerfield is the only town in the western half of this county which shows frequent lenticular deposits of till. They were noted at about one mile from Deerfield centre towards the north-east, north-west, west, and south-west. At a mile and a half towards the south-east are two fine hills of this kind, with the north summit of Mt. Pawtuckaway one mile farther east. Southward through this part of the county lenticular hills are very rare, the only examples discovered being Waterman's hill in the north part of Derry, a small one a fourth of a mile north-east of West Hampstead, one close north-east of Salem depot, and Spicket hill, east of Salem village. The last is very massive, and is associated on the east with the extraordinary development of these hills through the north part of Essex county, Mass. The only other lenticular hills observed west of the Boston & Maine Railroad in Rockingham county are Red Oak hill in Epping, the top of which is till, with its whole south-east slope; Dimond hill, and several others in the east part of this town; Grapevine and Bald hills in the south-west corner of Newmarket, the latter a very fine example, 150 feet in height; Deer hill in Brentwood, one mile north-west of Marshall's corner, also typical, about 100 feet in height; Beech hill in Exeter; and the several rounded masses of Great hill at the north-east corner of Kingston.

In Newington, Portsmouth, Rye, and a width of four or five miles next to the ocean southward, these hills are entirely absent, if we except the single instance of Great Boar's Head, described on page 254. Stratham has a few fine examples, as Stratham, Barker's, Bunker, and Rollins hills. Three occur within one mile east of Exeter village, and others one to two miles farther south-east. In the five miles next to Massachusetts line, these deposits of glacial drift are very numerous and massive, being more conspicuous than anywhere else in New Hampshire. They are 100 to 200 feet high, and are the only prominent hills in this region. Nearly all of them have received names, including Sweet and Brandy Brow hills, one and two miles east of Plaistow; Morse or Falls hill in East Kingston, and Buzzell, Martin, and Hog hills, crossed by the east line of this township; Moulton Ridge, Hoosac, Round, Gove, Conner, Ward's, Horse, and New Found hills in Kensington; Cock and Great hills in Hampton Falls; and Indian Ground, Chair, Sawyer's, Aspen, and Bugsmouth hills in South Hampton.

The longer axis of most of these hills noted in the west part of Rockingham county trends to the south-south-east; in Epping, Newmarket, and Brentwood, to the south-east; while those last described have almost invariably an east-south-east course. In Kensington and South Hampton, besides this trend of separate hills, we may detect their succession in two series which extend from north-west to south-east. One of these embraces, in order, Buzzell's hill, Moulton Ridge, Hoosac, Gove, Conner, Ward's, and Horse hills; the other consists of Martin, Hog, Indian Ground, and Chair hills. The two last named are double lenticular masses, the higher portion of each being at the north-west.

Lenticular Hills in Massachusetts. These remarkable accumulations of till are very abundant and conspicuous over the greater part of Essex county, Mass. The principal exceptions to this are the east part of Salisbury; Newburyport; an area several miles wide extending thence to the south-west; Cape Ann, eastward from Essex river; and the vicinity of Salem. Prominent lenticular hills in this county are Grape, Beech, Butts, Monday, and Powow hills in Salisbury, the last of which is perhaps their finest type found in all our exploration; Whittier's and Pond hills in Amesbury; Bear and Red Oak hills in Merrimac; Great, Golden, Silver's, West Meadow, and Scotland hills in Haverhill; Bear hill in Methuen; Reservoir hill in Lawrence; Prospect hill in Andover; Gage's hill and others about Great pond in North Andover; Hazeltine and Dead hills in Bradford; Bald Pate hill in Georgetown; Long, Pipe Stave, Archelaus, Ilsley's, and Crane Neck hills in West Newbury; the Old Town hills in Newbury; Ox Pasture, Hundslow, and Prospect hills in Rowley; and Turkey, Bartholomew, Turner's, Scott's, Town, Heartbreak, Plover, Sagamore, and Castle hills in Ipswich. Nearly all of these come within the limits of the map of these deposits, presented in the atlas of this report. Others occur farther south in this county.

Lenticular deposits of till are also very conspicuous in the vicinity of Boston. They form many of the islands in the harbor, and the numerous prominent hills that occur in the city and for five miles to the north and west, in the towns of Winthrop, Revere, Chelsea, Everett, Malden, Medford, Somerville, Cambridge, Watertown, Brighton, Newton, and Brookline.

The trend of these hills in Essex county is prevailingly towards the south-east; but some of them vary from this to nearly north and south, while others have their longer axis from west to east. Perhaps one fourth of them, however, are nearly round, having no well marked trend. This form is rarely seen in New Hampshire. About Boston their course is quite uniformly from north-west to south-east.

In the north part of Middlesex county lenticular hills of glacial drift are rare, but are represented by a few fine examples, as Fort hill in Lowell, on the east side of Concord river; Forest hill at the south-east edge of Dunstable, with another close north-east; and Blanchard's hill, with two others at the north-east, situated near the north line of Dunstable, west of Salmon brook. They are wanting in Pepperell and Townsend; but a prominent one is crossed by the east line of Ashby north of Lock's brook, and they are quite numerous in the next ten miles to the west.

In Groton and Ayer, lenticular hills are well shown along the east side of the Worcester & Nashua Railroad. Thence to the south-west they are rarely seen till we reach Worcester, where they are again abundant, especially for three or four miles north and west of the city, varying from 50 to nearly 200 feet in height. Reservoir or Chandler's hill, Newton, Prospect, and McFarland's hills are good examples.

Westward from Ayer along the Fitchburg Railroad, they occur at Shirley station, in the south part of Lunenburg, and prominently north and north-west of Leominster. At Fitchburg, and for several miles to the west and north-west, all the hills are ledgy with no important accumulations of till. Their notable abundance in New Ipswich and Rindge continues into Ashby and the north part of Ashburnham; but the next five miles to the south and south-west showed very few lenticular hills.

In Gardner, they again become numerous and prominent, Cowee's and Parker's hills being very conspicuous examples. From their tops as many as twenty of these hills are visible, mostly within two or three miles. Parker's hill is separated by a hollow of about 40 feet from a contiguous lenticular hill that rises at about twenty-five rods north-east to a nearly equal height. At the bottom of this depression, which is 100 feet above the foot of the hill in each direction, a former water-course, fifteen to thirty feet wide and four or five feet deep, filled with boulders from among which all the earth has been swept away, extends from north-west to south-east twenty rods or more. Its explanation seems to be, that while the ice-sheet was melting over this area, portions remaining at the north-west side of the hill turned a stream through this gap.

On Plate xviii of the second volume of this report, Prof. Hitchcock has shown the position of prominent lenticular hills in Bernardston and the north part of Gill. He also reports their occurrence in the north part of Montague; in Amherst, where Mt. Pleasant, other hills at the north and north-east, and the College hill are examples, also the hills in the south part of the town, called Castor and Pollux; in South Hadley, Prospect hill near the Seminary being of this class; and in the west edge of Granby.

The trend of these hills in the north part of Middlesex county is between south and south-east; about Worcester, Gardner, and Amherst, it is nearly north and south; while in Bernardston and Gill it is commonly a little to the west of south. Probably lenticular hills cccur at many other localities in this state, which has been specially explored for this report only in its north-east portion shown upon our map.

Cape Cod and Long Island. A hasty journey has been taken upon Cape Cod and Long Island, with a hope that some examination of the drift deposits near their southern limit might lead to a better understanding of the various questions suggested by exploration in New Hampshire. The description of Plymouth and Barnstable counties in the geological report of Massachusetts, and of Long Island in that of New York, seemed to indicate that these areas would show lenticular hills; but no accumulations like those which we have been describing under this name were seen.

The greater part of southern Plymouth county was found to be covered with modified drift. Much of this is spread in level plains, which in Middleborough have many shallow depressions that are occupied by swamps. In the west part of Plymouth the only hollows which break the plains are of small area with steep sides, containing ponds. These are so numerous that this township is said to have a pond for each day in the year. About Plymouth village the modified drift forms kame-like hillocks and small plains, which are separated by very irregular hollows and valleys. The tops of these deposits have a nearly uniform height which varies from 100 to 125 feet above the sea.

In the east part of Plymouth a massive ridge, known as Manomet or Rocky hill, extends three or four miles from north to south, having a continuous height 300 to 400 feet above the sea. Abundant angular boulders of all sizes up to twenty feet in diameter strew its surface, which seems to have no ledges, but to consist entirely of the very coarse glacial drift that we have called upper till. At the north end of this range the sea has undermined its base, forming a steep slope sixty feet in height. A section here showed twenty feet of upper till, yellowish, with abundant large and small boulders, nearly all of them angular, underlain by lower till, dark bluish gray, with small glaciated stones, exposed for twenty feet vertically but concealed below. The bed of boulders which forms the shore at this point came mostly from the upper stratum; their sharp corners and edges have since been worn away by the waves. This ridge is bordered on both sides by kame-like or nearly level areas of modified drift.

Southward, a broken range of lower hills, composed of the same coarse till, continues through Plymouth, Sandwich, and Falmouth. Thence it bends to the south-west, forming the chain of the Elizabeth islands. The highest elevations of this series of hills in Sandwich are about 300 feet, and in Falmouth and upon Naushon and the islands farther west, nearly 200 feet above the sea. Its length, from Manomet hill to the end of the Elizabeth islands, is forty-five miles.

Railroad cuttings thirty feet deep in these deposits, one mile north of Falmouth village and Wood's Hole, show only the upper till. All of Naushon island consists of the same material upon the surface, namely, mingled boulders, gravel, and sand, wholly unstratified. The boulders are often so abundant as to cover all the ground, and are of all sizes up to ten, or even twenty or thirty, feet in diameter. They are almost invariably angular, except as they have been rounded by exposure to the weather, none of them, so far as observed, being glaciated or water-worn. Cliffs forty or fifty feet high, which are being undermined by the sea south-west from Tarpaulin cove, appear to be composed entirely of this coarse upper till; but on the north-east end of the island a well sixty-seven feet deep passed through this deposit, and its last twenty-two feet were in very hard lower till, dark gray in color, with glaciated pebbles.

The contour of this island, as also of many localities throughout the whole series of these hills, is very irregular, consisting of hills, ridges, and rounds, with bowl-shaped hollows which frequently contain ponds. This feature has led some to regard these deposits as similar to kames.* Their material, however, is very different from that of the kames, which consist principally of stratified water-worn gravel, rarely containing any large or angular boulders, but frequently intermixed with layers of sand.

The conclusion of Mr. Clarence King, that this island, which he examined, forms part of a terminal moraine of the continental ice-sheet, seems to explain the accumulation of the till in this remarkable series of hills. The border of the ice-sheet probably remained almost stationary through a long period, in which the materials that it contained were being continually brought forward and deposited at this line of its melting. In many places these would be pushed into very irregular heaps and ridges by retreats and advances of the ice-margin. At the same time we should also expect that thick beds of ground-moraine would be gathered beneath the ice near its termination. The withdrawal of the glacial sheet would then leave these deposits as upper and lower till, one overlying the other, in a long but broken and undulating series of hills.

This terminal moraine does not, however, mark the farthest limit reached by the glacial sheet, which at one time extended six or seven miles beyond the Elizabeth islands, as shown by the prominent range of drift hills, which forms the north-west part of Martha's Vineyard. The origin of Cape Cod also seems to have depended upon this greater extension of the ice-sheet. Its terminal front appears to have continued from Martha's Vineyard north-easterly across Barnstable, thence to the east and north along the inner shore of the cape to Truro, which it probably crossed, extending onward to the north-east. This seems to be the outmost line at which we can assert the former presence of the continental ice-sheet.

Cape Cod, east from Sandwich, consists almost entirely of modified drift. Through Barnstable this is disposed in kame-like ridges, knolls, and small plains, separated by crooked and bowl-shaped depressions. The material here is gravel and sand, often obliquely bedded, with frequent boulders which appear to have been dropped upon these stratified deposits from floating ice. From Barnstable to South Wellfleet the surface is mainly level, consisting of plains of fine gravel or sand, and boulders are rarely seen. These plains vary in height from 25 to 75 feet above the sea. From South Wellfleet to High Head in the north part of Truro, the contour on the west side of the cape is again in very irregular kames, which are composed of gravel and sand with only rare boulders. These deposits, like those in Barnstable, rise to a height 100 to 150 feet above the sea. The east side of the cape is here a nearly continuous bluff of this height, horizontally stratified, being evidently a remnant of a nearly level plain, the east part of which has been washed away by the sea. Thick beds of clay have been exposed at a few points. At the Clay Pounds, near Highland light, the section is sand at the top, about 40 feet; finely laminated blue clay, also about 40 feet; then sand, with occasional layers of gravel containing pebbles up to six inches in diameter, exposed for 20 feet, and probably extending as much farther to the sea-level.

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* *Proceedings of the Boston Society of Natural History*, vol. xix, pp. 59-63; and *American Naturalist*, vol. xi, pp. 674-680.

The accumulation of these thick deposits of modified drift, occupying an area more than forty miles long, with an average breadth of five miles, remote from any large river, and bordered on each side by the sea, seems capable of explanation only by supposing the material to have been held in an ice-sheet, which extended to the line that we have indicated, covering the Vineyard sound, Cape Cod and Massachusetts bays, and thence reaching to the north-east over a large part of the Gulf of Maine. When the return of a warmer climate drove back the front of these ice-fields to the long terminal moraine of the Elizabeth islands, Falmouth, Sandwich, and Plymouth, the rivers which flowed from their melting surface were principally discharged at two points, those at the south-west converging towards Barnstable, while those which descended from the glacial sheet over Massachusetts bay had their mouth in Wellfleet and Truro. The bordering walls and irregular masses and ridges of ice, which beset these rivers at their points of escape from the ice-sheet, caused their deposits over these areas to be massed in kames. The ocean at this period stood 150 feet or more above its present height; and the part of the burden of these glacial rivers, which was carried beyond their mouths, was spread by marine currents in nearly level plains, bordering the front of the ice-sheet. The true terminal moraine of till, formed by the ice at this bound of its greatest extent, is covered by the sea or by these beds of modified drift.

The north end of these Champlain deposits is at High Head. The whole of Provincetown consists of sea-sand, with no pebbles. This sand has come from the erosion by the sea of the east shore of the cape; has been swept north and west to its present place in the lee of this breakwater; lifted by the waves into beach-ridges; and further raised by the wind into hills a hundred feet in height.

On Long Island the farthest limit attained by the ice-sheet is probably indicated by a series of drift hills, which is commonly known as the "backbone of the island." These hills are well exposed along the south shore for about ten miles west from Montauk point, forming cliffs from 20 to 140 feet high. Westward, they extend through the north part of East Hampton, and from Sag Harbor south-west to the Shinnecock hills and Canoe place. Thence they continue in a nearly west course, including Osborn's hill, a few miles south-west of Riverhead; Terry's hill, south of Manor; Holman's hill, north of Yaphank; the Coram, Seldon, and Bald hills; Mount Pleasant, west of Ronkonkoma lake; Pine hill; the Commac, Dix, and West hills; Spring, Wheatly, and Harbor hills, the last of which, near Roslyn, is the highest point on this island. Farther west, this series of hills trends a little more to the south, passing near Lakeville, and close north of Creedmoor, Jamaica, and East New York. Thence it nearly coincides with the south-east boundary of Brooklyn, and reaches to the Narrows, forming the sites of Cypress Hill cemetery, Ridgewood reservoir, and the cemetery of the Evergreens, of the highest portions of Prospect park and Greenwood cemetery, and of Fort Hamilton.

The length of this range from Montauk point to the Narrows is about 115 miles. It is interrupted at Neapeague beach and marsh, 12 miles west of Montauk point; between Manor and Yaphank; and at Syosset. West from Roslyn it is very plainly recognized as a continuous, irregularly undulating ridge. The heights of prominent hills in this series are as follows:* Montauk point, 85 feet above the sea; Fort Pond hill, five miles to the west, 194; Neapeague hill, 135; Amagansett hill, 161; Shinnecock hill, 140; Osborn's hill, 293; Ruland's hill, south of Coram, 340; Jane's hill, the highest of the West hills, 354; Layton's or Wheatly hill, 380; Westbury hill, 260; Harbor hill, 384; John M. Clark's hill, near Manhasset, 326; Smith's hill, 332; Prospect hill in Brooklyn, 194.

In the east and middle portions of the island the majority of these hills are composed of modified drift, being gravel and sand, distinctly stratified, and containing few or rare boulders. Osborn's, Ruland's, Jane's, and Harbor hills are of this kind. They appear to be immense kame-like deposits, formed at the terminal front of the glacial sheet. As at Cape Cod, when this was obliged to retreat, its melting took place over a very wide extent of its surface; and the rivers thus formed were heavily freighted with gravel, sand, and clay, which had been contained in the ice. A large portion of this gravel and sand would be heaped at the mouths of these streams,—that is, at the points where they left these ice-fields and entered the lower open area beyond.

The part of Long Island south of these hills consists of nearly level plains of fine gravel and sand five to ten miles in width, and extending a hundred miles in length. The height of their north portion at the foot of the hills varies from 50 to 150 feet above the sea. These deposits, like the levelly stratified drift of Cape Cod, appear to have been brought by the glacial rivers which formed the kame-like hills. The ocean rolled its waves above the surface of these plains, spreading the material which it thus received over a wide area to the south.

Near the west end of Long Island this range of hills is composed entirely of unstratified glacial drift, full of boulders, having all the characteristics of the upper till. It is well exhibited in the south-east part of Brooklyn by many excavations, as for cellars and streets. This is the true terminal moraine of the ice-sheet. Its continuation eastward is for the most part covered by the later kame-like gravel and sand. Westward, this terminal moraine, principally composed of coarse, unstratified drift like the upper till, heaped in irregular hills and ridges, begins on the opposite side of the Narrows at Forts Tompkins and Wadsworth, crosses Staten island, and enters New Jersey† at Perth Amboy; it bends thence to the north-west and north, passing near Plainfield, Morristown, and Dover; next it runs west and south of west by Hackettstown to the Delaware river a little above Easton.

The boundary of the ice-sheet at its period of greatest extent appears to be thus plainly marked for a distance of three hundred miles, reaching from Truro, near the end of Cape Cod, through Barnstable, the north-west part of Martha's Vineyard, Block Island, Montauk Point, the centre of Long Island, the south-east part of Staten Island, and northern New Jersey. Careful exploration will probably discover a similar series of hills, composed of unstratified upper till or of modified drift, at the border of the glaciated area through Pennsylvania, Ohio, and states farther west.

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* From articles on the geology of Long Island, by Mr. Elias Lewis, Jr., of Brooklyn, in *American Journal of Science and Arts*, third series, vol. xiii, pp. 235 and 236; and in *Popular Science Monthly*, vol. x, pp. 434–446. The greater part of these heights were determined by the United States Coast Survey.

† The course of these hills at the most southern limit reached by glacial action in New Jersey is from the annual report for 1877, of Prof. George H. Cook, the state geologist. He says,—"The whole line of this moraine is remarkably plain and well defined."

A later terminal moraine seems to be indicated by the line of drift hills which forms the north shore of Long Island through the greater part of Brookhaven, Riverhead and Southold. Its extension to the east appears to be through Plumb and Fisher's islands, and the southern edge of Rhode Island; thence to the Elizabeth islands, and from them northward to Manomet hill. At this line the ice-sheet made a long halt in its retreat. No similar series of drift deposits has been noticed farther north in New England, over which the melting of the ice-fields seems in general to have been without sufficient pauses for the formation of definite terminal moraines.

It remains for us to inquire what was the origin, or mode of accumulation, of the lenticular hills and slopes of till which have been found to be abundant and prominent in many parts of southern New Hampshire. We have seen that in Cheshire, Hillsborough, and Rockingham counties these lenticular masses are scattered here and there, and in some places quite thickly, upon three areas which vary from five to twenty miles in width, and extend twenty-five or thirty miles from north to south, or from north-east to south-west. The greater part of the most eastern of these areas lies beyond the state line in Essex county, Mass. These tracts are separated by others of equal or greater width, upon which scarcely any lenticular hills are found. This territorial division in three groups does not appear to have been caused by differences in the adjacent stratified rocks; it more probably resulted in some unexplained way from movements of the ice-sheet. It is the only indication of system which we have discovered in the distribution of these hills. Whether they occur rarely or very abundantly, they are alike irregularly scattered without any apparent order or connection, nowhere forming well defined series, like those of the terminal moraines of Plymouth and Barnstable counties in Massachusetts, and of Long Island and New Jersey.

In Sullivan, Carroll, Belknap, Merrimack, and Strafford counties, lenticular accumulations of till are sprinkled more sparingly, with no traces of system, being numerous in some localities, but generally rare or absent. With this diminution in numbers northward, the relative proportion of lenticular slopes of glacial drift resting against ledgy hills is increased. Carroll county is especially remarkable for the frequent occurrence of these slopes on the north-west side of hills, directly facing the powerful current of the ice.

Nearly the whole of New Hampshire presents a very uneven surface, consisting of broken and irregularly grouped hills and mountains. The distribution of the lenticular hills does not seem, however, to depend upon these features. They are very finely developed on the lowland near the coast, but not less so in Dublin, Jaffrey, and Rindge, upon the height of land between Merrimack and Connecticut rivers. Beside the coast they are spread over an area which would otherwise be nearly level; at many places inland they are equally abundant among high, irregular hills. They seem as likely to be found upon one side as another of any mountain or prominent hill-range. The altitude at which they occur varies from the level of the sea to 1,500 feet above it. By reference to a map in the atlas, the relation of the lenticular hills to contour lines and striæ will be readily seen.

The most noticeable feature of these remarkable deposits is their smoothed oval form with a definite trend or longer axis, which lies almost invariably in the same direction with the striæ. Thus their position is the one which opposed the least resistance to the glacial current, and is that which would be assumed by accumulations formed beneath the moving ice-sheet. Deflection in the trend of these hills at any locality from their prevailing course over adjacent areas is usually accompanied by deflected striæ. An instance of this occurs in Dublin on the north side of Monadnock mountain, where both lenticular hills and striæ point thirty or forty degrees more than usual to the east of south. A similar deviation of the striæ has been noted at Andover and Potter Place, on the north side of Mt. Kearsarge, but no lenticular hills occur there. It would appear that any isolated mountain like these, while enveloped in the ice-sheet, might cause only slight variation in its current, which must overcome as great resistance in turning aside as in passing upward without changing its course; but near the end of the glacial period, when such barriers were reached by the retreating terminal front of the ice, its current from the north would no longer be pushed upward by the continuous glacial sheet, so as to pass over the mountain, but would be deflected toward the vacant area at the south-east. It seems probable, therefore, that the hills mentioned were moulded with their unusual trend during the decline and departure of the ice-sheet. Such deflection of the lenticular hills is uncommon, their trend being nearly uniform over large areas, gradually changing from a south-east course in Carroll, Strafford, and Rockingham counties, to a nearly south course in the west part of the state.

The till of Scotland is described by Mr. James Geikie,* as massed in ridges which seem to be somewhat like our lenticular hills, but more prolonged and less prominent. His opinion that these accumulations of the Scottish till were formed beneath the ice-sheet, seems to be true also of the lenticular hills and slopes of New England. The reasons which lead us to this conclusion are the distance of these deposits from the end or outside limit of the ice-sheet, as it probably existed through the greater part of the glacial period; their difference from the hills and ridges of the terminal moraines there formed; the trend of the lenticular accumulations; their composition principally of lower till; the occurrence in this till of level sandy layers; the similarity of the lenticular hills to slopes which rest against ledgy hills, either upon the side which was sheltered from the ice-current or upon that which was fully exposed to it; and the obscure lamination, which may be commonly observed in sections of the lower till, whether in lenticular masses or in flattened sheets.

Below a thin covering of upper till, the material of which the inner portion of these hills and slopes is formed is the dark and compact lower till, which has been described on pages 9 and 286. It has been shown that the character of this deposit can be explained only by supposing it to be the ground-moraine accumulated beneath the moving ice-sheet. The small proportion of its iron that has become fully oxidized, and the very fine clayey detritus in which its glaciated pebbles and boulders are embedded, indicate that this portion of the drift has been mostly derived by erosion from the rocks, and pulverized under the grinding action of the ice-current.

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* "In the Lowlands the effect produced by the varying direction and unequal pressure of the ice-sheet is visible in the peculiar outline assumed by the till. Sometimes it forms a confused aggregate of softly swelling mounds and hummocks; in other places it gives rise to a series of long smoothly-rounded banks or 'drums' and 'sowbacks,'.which run parallel to the direction taken by the ice. This peculiar configuration of the till, although doubtless modified to some extent by rain and streams, yet was no doubt assumed under the ice-sheet." —*The Great Ice Age*, American edition, p. 88; second edition, revised, p. 76.

This explanation is quite different from that advanced by Prof. N. S. Shaler, respecting the lenticular hills of eastern Massachusetts, in the *Proceedings of the Boston Society of Natural History*, vol. xiii, pp. 196–203. He supposed these hills in the vicinity of Boston to be remnants spared by the fluviatile and tidal erosion of a once continuous sheet of drift, which had been contained in a glacier that descended the Charles River valley and was deposited at its melting.

The level layers of gravel, sand, or clay that are occasionally found in this lower till appear to have been formed by streams, which in summer found their way through crevasses to the bottom of the ice. These seams and beds of modified drift in the till frequently occur upon lenticular hills and slopes, where they could not have been deposited by ordinary streams, if the ice-sheet was withdrawn. The usually horizontal position and considerable extent of these beds show that after their formation they lay undisturbed, while the ground-moraine continued to be deposited above them. Where similar seams or beds are nearly vertical, inclined, or contorted, as they are more rarely observed, it shows that a large mass of the lower till was lifted up before the ice-current, and pushed forward with its included layers of modified drift.

The accumulation of these hills and slopes seems to have been by slow and long continued addition of material to their surface, the mass remaining nearly stationary from the beginning of its deposition. Obviously this was the case with the lenticular slopes gathered behind the shelter of higher ledgy hills, or upon their opposite sides. Except in their location, these slopes are like the lenticular hills, which seem to contain no ledge, being simply heaps of the ground-moraine 50 to 200 feet in height. This resemblance suggests that both hills and slopes alike increased slowly in extent and depth without much change in place, new material being lodged upon their surface from the ice-sheet which swept over them.

The obscure lamination or cleavage, which is one of the characteristic features of the lower till, was probably produced by this mode of its accumulation. In this deposit from the ice-sheet, it corresponds to the stratification of sediments from water, but it is less distinct; and the fine detritus in which it appears contains glaciated pebbles and boulders indiscriminately mixed through its whole mass. This structure was at first thought to be a true cleavage, caused by the pressure of the glacial sheet. If we take this explanation, it still proves, like the hardness and compactness which also mark the lower till, that this deposit was not ploughed up by the enormous pressure of the ice passing over it. How could this force permit the ground-moraine to be heaped in the steeply-projecting lenticular hills? Instead of this we should expect it to be left only in flattened sheets or behind sheltering ledges. The probable answer seems to be, that the finely pulverized detritus and glaciated stones in the bottom of the ice-sheet had a tendency to lodge upon the surface of any deposit of the same material. When such banks of the lower till became prominent obstacles to the ice-current, its levelling force was less powerful than this tendency of adhesion, which continually gathered new material, building up these massive rounded hills. At the melting of the overlying ice-sheet, the surface of hills and valleys, ground-moraine and ledges, were alike covered by the nearly continuous mantle of the upper till. W. U.

NOTE UPON LENTICULAR HILLS, BY C. H. HITCHCOCK.

Thorough search for these moraines has been made in all parts of the state south of the White Mountains, not including Grafton county. Not many more will be added by future observations. I do not think any occur in Grafton county. In Canaan, long drift covered hills south of the centre bear some resemblance to them. A trip through eastern Vermont revealed facts of interest. In Orange two hills in the south-west corner resemble lenticulars, and, as seen from a distance, there appear to be genuine examples on the north-west side of the church. In Peacham and Danville, numerous rounded hills resembling these moraines may be seen from elevated positions. Some that I examined proved to be composed of limestone, weathered roundish; so it seems probable that all the others are similarly constituted. One not familiar with the behavior of this rock, when acted upon by atmospheric agencies, might call all these mounds lenticular hills. Large drift hills are known to occur in Bethlehem and Whitefield. Another trip to the localities would be requisite to enable me to pronounce upon their existence in these towns or elsewhere in Coös county. It seems probable that the great drift hill just west of Chocorua pond in Tamworth should be of this character. The heliotype illustration of some of these hills in Goffstown admirably represents their general character. All the hills in the view are true lenticular ground-moraines, with no ledges in them. They are simply piles of earth and stones accumulated beneath the ice-sheet, and afterwards covered by the upper till. The information contained in Mr. Upham's description of these hills is one of the most valuable contributions to science obtained during our whole survey of the state.

Lake Ramparts.

Under this name I have described in earlier state reports ridges of boulders and coarse gravel bordering certain portions of shallow ponds. They occur where the water is not deep, and there is a considerable exposure of shoal bottom strown with boulders. As the water freezes in the winter the ice encloses these stones, and by virtue of expansion moves them nearer the shore. The amount of pushing in a single season would be small; but the work would be resumed every winter, and in the course of ages the fragments would reach the shore, and perhaps be crowded inland. Farmers who build fences on the edges of a wide ditch often find them bent or prostrated in the spring for a similar reason; the expansion of the water in freezing has pushed them over.

Several instances of these ridges have been observed in New Hampshire. The best known is on the Vaughan shore in Moultonborough, in the north-east part of Lake Winnipiseogee. We find there a ridge one eighth of a mile long, opposite a broad expanse of shallow water about four feet in height. Passing easterly 125 feet, the ground is low and swampy, and another similar ridge about fifteen feet high is encountered, fronting a low terrace. It is very likely this ridge represents an older rampart, made when the lake stood at a higher level. The shore and the ridges are covered by shrubs and trees. A pine had been cut recently from the smaller rampart, whose trunk has a diameter of twenty-eight inches. From this I obtained a section for the museum, and counted 122 rings of growth upon it. As this had been cut twenty-five years previous to my visit (1871), it is obvious that certainly a century has elapsed since the formation of the rampart. I saw a tree still standing upon this ridge twenty-seven inches in diameter. A few years since, in the case of the town of Gilford *v.* The Winnipiseogee Lake Company, it was found expedient to use the facts shown by this rampart with the trees upon it, to prove that there had been no unusual flowage of the lake for the past hundred years. The whole court adjourned to visit the locality. Fig. 62 shows the two ramparts with a tree

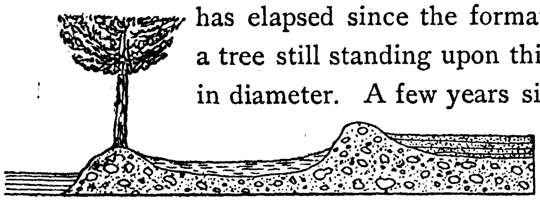

Fig. 62.—Lake Rampart, Moultonborough.

standing upon the first. Another example may be seen at the south end of Long island. It is possible that Steamboat island and its culmination south in a ridge in shallow water is to be regarded as one of these ramparts.

SEA WALLS.

A variety of the sea-beach action is indicated by the term *sea walls*, which I suggested for them in 1861.* It is a long embankment of smooth boulders, without sand or gravel, lying just behind the beaches. When the more powerful storms prevail off the coast, stones up to two feet in diameter are carried a distance of hundreds of feet, and deposited just back of the beaches. Sometimes they are fifteen feet in height. I have noticed them in Rye.

DISTURBANCES IN MODIFIED DRIFT.

A few examples of curvature in layers of gravel and sand have been noticed. One of them is represented in Fig. 63. It is seen on the east side of John's river, in Whitefield, just east of the depot. Coarse gravel occupies the centre and lowest part of the arch, and there is another mass of it upon the steep slope to the left. The bank was exposed for about fifteen feet.

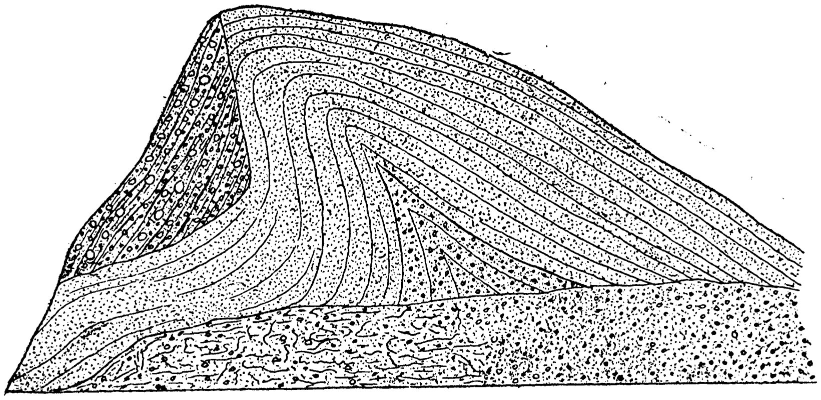

Fig. 63.—SECTION IN GRAVEL, WHITEFIELD.

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* *Preliminary Report Geology of Maine*, p. 270.

Another style of disturbance is indicated in faults, some of which have been referred to upon page 39. Many of them can be regarded as the result of local sliding. One more difficult to explain may be seen between Mink brook and the village of Hanover upon the West Lebanon road. The first bank next the brook, below Mr. Benton's house, dips 10° northerly. Near the base of the principal hill, north of Benton's, the dip is southerly at the same angle. Near the top the stratification is horizontal. The section along the road shows the loamy sand to have a synclinal structure, or, rather, there are two faulted segments dipping towards each other. Other highly inclined masses of alluvium occur close by the railroad depot in Norwich, at the north edge of the great plain two miles from Dartmouth college on the Lyme road, and near the mouth of Grant brook in Lyme, where the angle of inclination amounts to thirty degrees. It seems likely that the forces disturbing these terraces were analogous to the elevating agencies that displayed their power in the earlier periods of geological time. Earthquakes of greater severity than are now common in the state might have been adequate to produce the results. The facts are given to draw the attention of other and future observers to the subject, as they may find more important illustrations of a continental force, or else discover satisfactory evidence that the disturbances have been entirely due to gravity.

ICE ACCUMULATIONS.

Occasionally the conditions are favorable for the continuation of ice unmelted through the entire summer. The best known example is in Tuckerman's ravine, described in Volume I, page 623. Here it is exposed to the sun and air, continuing very long because of an immense accumulation. In other cases the ice is preserved in caverns, or in the midst of large fragments of rock, as in Lyman, Effingham, and Plymouth.

In Lyman, about half a mile west of Parker hill, ice accummulates beneath large stone fragments at the base of a cliff. I found no ice there September 4, 1870, though the air issuing from the side was very cold, indicating its existence. The people in the neighborhood often obtain ice from this locality in the summer. In a journal published in Concord in 1823, it is related by Caleb Emery, of Lyman, that in 1816, a memorable cold summer, he saw a well frozen over solid, eight feet from the surface, in June. The ice had to be cut to enable the draught of water. In July, he found a mass of ice floating in this well as large as a wash-tub.

In Plymouth, there is said to be an ice-cave in the west part of the town, where ice can be obtained every summer as late as the month of August.

Upon the north slope of Green mountain in Effingham I found large masses of ice in the latter part of August, 1875. Near the edge of a precipice enormous blocks have been separated from the ledges, making large passages like caves, where different fragments rest upon each other like arches. On descending twenty feet I found ice, and then followed along forty feet to a much larger opening. This ice-cellar is well known to the people living in the neighborhood.

A study of similar ice-masses elsewhere shows the existence of currents of air, downward in the summer and upward in the winter, which evaporate the water, and, by the accompanying removal of heat, induce cold sufficient to freeze water and to preserve the ice thus formed. The principle has been made use of in warm countries to produce ice artificially in merchantable quantities.

Beaver Dams.

Several bogs in the state owe their existence to the former presence of the dams made by beaver. This animal is now entirely extinct, owing to the advance of clearings and the removal of the forests. It is not uncommon to find sticks that have been gnawed by these creatures. One such example is in Plainfield, where they occur underneath pine trees more than a foot in diameter. It is plain that here a bog was filled up by the natural accumulation of sediment in the beaver pond, and the land became dry enough for pines to grow. The name of "beaver meadow" is frequently heard throughout the state, and indicates the prevalence of bogs reclaimed by animal agency. One of the largest of these lies between Mts. Misery and Odiorne, in Weare, on the land of Hon. Moses Hodgdon, nearly a mile in length. It is used for grass, and in wet seasons is often flooded with water. Logs occur quite deep down, in a soft mud in which poles can be thrust for several feet.

North America in the Ice Period.

Candid geologists admit that no part of their knowledge is so obscure as that of the cause of glacial cold. Various theories have been suggested to account for it, but none of them command universal acceptance. Before it can be properly answered, we shall find it necessary to consider somewhat the conditions of glacial envelopment, the dimensions of the areas occupied by the ice, and the directions in which movement has been effected. In such a study we shall find it necessary to look far beyond the confines of New England, for the movements in this comparatively limited area are unlike those occupying the greater part of the continental ice-sheet. Some of the difficulties we have experienced in generalizing our observations result from the smallness of our field of study. I will therefore present upon a small map of the north-east portion of our continent a delineation of the areas occupied by the ice in its period of maximum development, with arrows to indicate the principal directions of movements. An examination of this map, with a brief description of the principal features of glaciation may furnish the means for satisfactory generalizations respecting the origin, extent, movements, and duration of the ice-sheet.

The Alps of southern Europe furnish the most accessible example of glaciers in action, with indications of greater extent in the ice-period. The higher portions of the range are occupied by immense fields of snow, which are the source of the numerous glaciers pushing out from it on every side, both towards Switzerland and France on the north, and towards Italy upon the south. These glaciers may be said to radiate from a central line of dispersion. In the Alpine district the accessible glaciers behave like streams of water, occupying only the bottoms of the valleys, and descending to the lower levels apparently in obedience to the laws of gravity. A study of the former extent of these glaciers indicates their former extension across the valley of Switzerland to the Jura mountains. The Rhone glacier moved over the great valley to the Jura mountains, occupying an area 50 miles wide, 150 long, and 2,000 feet deep. Lateral, medial, terminal, and ground moraines occur in connection with all these glaciers. Large boulders have been transported from Mt. Blanc to the Jura.

An example more nearly analogous to our own is afforded by the former extension of the Scandinavian glaciers. Erdmann's map represents striæ pushing northerly into the Arctic ocean; south-easterly, in the promontory between the gulfs of Finland and Bothnia; south-east and south, varying west of south, also, in the lower part of Sweden; west, north-west, and south-west, in Norway towards the Atlantic ocean. Croll supplements this map, by showing the continuation of the southerly course into Prussia; a bending of the direction to conform with the Baltic sea, passing over Denmark to both the south and north of England. Scotland and England are made to send off additional ice-currents; and the western edge of the ice-sheet reaches to west longitude 14°, or as far as the seaward limit of comparatively shallow water. This area is certainly 1,700 miles wide, and 1,500 from north to south. This will compare favorably in size with our American glaciated area. The latest authorities show that the phenomena are all explicable by the existence of a principal central ridge of dispersion in Scandinavia and subordinate ones in Great Britain; also, that there is no evidence of the flow of ice from the polar regions into northern Europe. There exists, therefore, a close analogy between the glacial conditions of Scandinavia and North America;—and if the former can be explained upon the theory of a centre of dispersion, so can the latter.

Before considering the location of the American centre of dispersion, it will be well to recall the glacial conditions existing at the present time in Greenland, since they will illustrate the state of things in New England during the period of the greatest cold. We discover there how the ice can move up hill, and how the ground moraine can be formed.

Glaciers in Greenland.

Greenland was discovered by Gunnibiorn in 872. In 983, Eric the Red, banished from Iceland, established a colony near the south end of Greenland, imposing upon it the name it now bears. The settlement prospered; and indications of civilization left behind by these Norsemen exist as far north as Upernavik (latitude 72° 50′), or as far north as the stoutest ships of modern times can sail without encountering serious risk. The population increased sufficiently to require the services of a bishop; and a list of seventeen of them, from 1126 to 1406, has been preserved. A change of political relations led to the destruction of the commerce between Greenland and Scandinavia, and, followed by attacks of pirates, and the Skraellings or Esquimaux, led to the complete extermination of the Norse colony. The history of the last man has been preserved in Icelandic annals, whose death occurred early in the fifteenth century. Europe has been in doubt respecting the fate of this colony ever since, it having been claimed very recently that it was established on the eastern coast, and that the descendants of the original settlers might still be found there, shut off from the rest of the world by ice that had increased in amount since the last ship had communicated with them. The name *East* Greenland has led to confusion, since it might be interpreted to signify the coast looking towards Iceland instead of Baffin's bay. The most southern of the settlements upon the south-west coast was *east* of the others, and hence the use of the term East Greenland. The ruins of ancient churches and monuments found on the south-west coast clearly confirm the truth of the Icelandic *sagas*.

The island is almost continental in dimensions (perhaps consisting of an archipelago), being over 1,200 miles long and 400 broad, as far as from Boston to the mouth of the Rio Grande, or to Utah. The interior is covered by a field of ice, never entirely traversed by any human being. From three points attempts have been made to learn something of its nature. In 1830, Keilsen went 80 miles inland from Holsteinberg (latitude 67°), reaching the edge of the ice-sheet, which could not be climbed.

Nordenskiold, in 1870, went in 30 miles, reaching the altitude of 2,200 feet. He observed that the ice rose gradually towards the interior. The outer edge is a high wall. Once entered upon the broad surface of the ice, it is like travelling upon the sea, away from all sight of land. From North Greenland Dr. Hayes penetrated to a distance of 70 miles. It was a day's journey to the wall from the sea. The second day was spent in climbing to the table-land; the third day allowed a progress of thirty miles, the angle of ascent falling from 6° to 2°. On the fourth day an ascent of 5,000 feet was reached, not the highest point,—but the weather became too inclement to permit a longer stay. The view was that of a frozen Sahara, immeasurable to the human eye.

It is probable that Greenland slopes westerly in general, thus placing the highest ice-ridge near the eastern border; for there are very few icebergs off the eastern coast, such as would be seen if the glaciers discharged themselves as they do upon the western side. At the rate of increase indicated by the observations of Hayes, the height of land may be averaged at 5,000 feet, and the thickness of ice above it as 10,000 feet. This flows mainly into Baffin's bay, Smith's sound, and the other waters to the west. A northward transportation is indicated at Polaris bay, where Dr. Bessel found numerous granitic rocks containing peculiar garnets, such as abound in South Greenland, resting upon Silurian limestones. On the western side are no less than thirteen well marked glaciers discharging their bergs into the sea, as far north as Upernavik, about 73° north latitude. The largest ones occur further north, some of them being 3,000 feet thick. The bergs derived from them are of this thickness, as measured by Hayes. The Humboldt glacier enters Smith's sound with a width of 60 miles, the ice-cliffs, from 50 to 300 feet high, extending 2,000 feet deep in some places. The adjacent rock-cliffs are 500 to 1,000 feet high.

The derivation of icebergs from glaciers is well proved. The glacier pushes down the fiörds into the sea, till the buoyancy of the ice, lifted up by the waters, causes it to separate in large blocks which float out to sea, urged onwards by the land motion, and afterwards by the oceanic currents. Baffin's bay and Davis straits are filled with these bergs, which float southerly till the warmer air and water of the lower latitudes dissolve them. It is uncommon to see them as far south as 40° north latitude. The romantic history of Tyson's party illustrates the long continuance of floating ice. This party consisted of nineteen persons, and they floated southwards 1,800 miles in six months' time, before they were rescued,—October 16 to May 1.

These bergs often carry earth and rocks in immense amount. Scoresby saw some carrying from 50 to 100,000 tons of material. Every Arctic traveller describes them. This rubbish falls to the bottom as fast as the bergs melt or topple over. It has been suggested that much of the Great Banks of Newfoundland has been accumulated from the leavings of icebergs.

Greenland may be compared to a broad platter slightly inclined westerly, with occasional chinks in the sides through which the ice discharges itself, as if it were a viscous body. We might say the ice accumulates in immense amount till it makes a conical pile like a heap of grain upon a floor. When additions are made to the grain upon one side, a motion is induced, and more of the kernels will flow down on that side than were added, because of cohesion. If the floor be slightly inclined, the flow of grain would be greatly facilitated. In a similar manner we may believe the flow of ice down certain valleys will carry with it other parts of the ice sheet, even where much of it is dragged over hills. This rise would always be less than the amount of descent from the top of the ice accumulation. With the ice would be carried the blocks of stone imbedded in it through the pressure of the weight of the overlying mass. Except near the coast, none of the Greenland ice would show boulders upon the surface, because, unlike the Alpine *mer de glace*, the mountains are entirely covered, and no moraines could be accumulated by the falling down of fragments from the hillsides. The moraines of Greenland are therefore different from the ordinary heaps displayed on the sides, tops, and ends of Swiss glaciers; they must accumulate mainly beneath the ice-sheet, and not be visible so long as the ice remains unmelted. The finer parts and the favorably situated blocks would, however, be carried along with the glacier to some extent, to be distributed eventually as submarine deposits, or to become a species of residual moraine after the melting.

Further peculiarities of distribution appear in connection with the subglacial streams. From the ends of the glaciers issue muddy torrents derived from the melting of the ice. Immense supplies of heat penetrate the ice from the sun's rays, which must give rise to very much water, seen also in the numerous surface lakes and streams. As all water seeks the lowest levels attainable, these currents will find a place at the bottom of the ice-sheet, and wear away the rocks and ground-moraines already accumulated into the sea. Hence will arise banks of earth or clay more or less continuous from the ice cliff to the point where the current ceases to transport material. In these banks would be found remains of such marine animals as lived in the vicinity. These deposits remind us of the fossiliferous clays along the coast of New England, sometimes attaining an altitude of 150 feet. Boulders would occur in this clay, brought by bergs, so that it might be styled boulder clay. This deposit is analogous to that called the Champlain clays.

Evidence has been often stated showing that the south end of Greenland, for a space of 600 miles, is sinking, and the north end rising. Tyson and Bessel speak of marine shells found 1700–2000 feet above the sea level near Polaris bay. If there were shoal water between Greenland and Labrador, the glaciers would push across to the main land of the American continent.

The American Centre of Dispersion.

It seems probable from the latest grouping of facts that some part of the Labrador peninsula may be considered as the centre from which the ice west and south-west from Greenland has radiated. Greenland may be regarded as an area by itself, never confluent necessarily with the Labrador or principal American ice-sheet. The various facts in support of this view will now be stated.

The greatest amount of glaciated territory indicates a south-westward course. This is seen over the highlands between Hudson's bay and the St. Lawrence valley, the valley itself, western New York, Ohio, and so on to the extreme west edge of the drift. It is very prominent from the Lake of the Woods and Lake Superior, near the national boundary to the Rocky Mountains. In New England the dominant course is south-easterly, with both south and west of south directions. The same is true of New Brunswick and Nova Scotia. Accounts differ for Newfoundland. J. F. Campbell's observations indicate greater variation, possibly a radiation in every direction. Murray's observations are said to show a south-westerly course, but a recorded observation from him is about S. 30° E. On the east coast of Labrador the map shows several fiords, as if there had been an ice-sheet upon the upper part of the peninsula moving north-east and east. Hind finds glacial markings on the Moisie river, and notes a remarkable absence of boulders up to 1,000 feet in height. He does not state in what direction the ice moved. Prof. O. M. Lieber's sketches in the coast survey report do not suggest universal, but local glaciation, as if the ice came from the peninsula itself, not from Greenland. Packard describes glacial markings in the Hamilton inlet fiörd running to the north-east. On the southern shore, Packard thinks the movement was to the south-east, towards Newfoundland.

Farther north, the Meta incognita just north of Hudson's straits shows an extensive *mer de glace* with glaciers moving southerly, and, most likely, northerly also. McClintock describes boulders at Leopold harbor (North Somerset), and at Graham Moore bay (Bathurst island), which have been transported 100 and 190 miles north-east and north-west. West of Hudson's bay, all explorers describe glaciated conditions, but give scarcely any data to enable us to learn the direction of the movement. In Franklin's first voyage (1819–22), loose stones are described, whose "angular forms" militate against their having travelled great distances. In his second voyage are quite a number of notices, implying transportation in a westerly direction.

There is a marked difference in the distances to which boulders have been transported by the south-west and south-east currents. The latter, as indicated heretofore, are not known to have travelled as much as 100 miles. The average distance may not exceed 12 to 15 miles, and there are no boulders in New Hampshire that have come from the north side of the St. Lawrence, nor from great distances in Maine on the north-east. In Ohio many have come from more than 100 miles. Boulders of native copper in Iowa and Wisconsin have travelled from 300 to 465 miles. The greatest transportation in the north-west region has been that of boulders from the Lake of the Woods, 700 miles towards the Rocky Mountains, upon British territory. Transportation upon ice-floes or bergs has been greater, as from Canada West to Baton Rouge, La.; but the others were mostly ice-carried. The greater south-west transportation seems to be connected with topographical features, viz., the continuation of this St. Lawrence valley to the south-west and south.

The distance of observed continuous south-westerly striation from the Laurentian highlands to the base of the Rocky Mountains is about 1500 miles. From central Greenland to the same place it exceeds 2500 miles. We have the means for determining approximately the thickness of the ice-sheet requisite to cause a flowage. It would require an average slope of about one half of a degree to make the ice move reasonably fast. This is forty-six feet to the mile, or one foot rise in every 115 feet of distance, or one mile for every 115. These data would necessitate an ice-cap 13 miles high if the centre of dispersion were in Labrador, or 22 miles for the whole distance to central Greenland. Making use simply of what would be required to move the ice over New England, we find that 800 miles represents the distance to central Labrador, requiring a cap 7 miles higher than Mt. Washington, or over 8 miles thick in all. If the movement came from Greenland, the distance is estimated at 2,000 miles, and the elevation of the ice-cap at 17 miles above Mt. Washington Prof. Dana, from somewhat different data, obtains smaller results. Assuming the starting-point to have been on the height of land between the St. Lawrence and Hudson's bay, and the descent at 15 feet per mile, the sheet must have been at least 13,000 feet thick above the land to carry it over Mt. Washington. These figures sound less formidable, but the slope does not seem adequate to have produced the results.

Prof. Torell, of Sweden, read a paper before the American Association for the Advancement of Science, in 1876, advocating the source of the American drift to have been in Greenland. He writes thus:*

> It has been the opinion of many distinguished American geologists that the source of the eastern ice fields is to be sought in the Canadian highlands. Against this opinion several important reasons may be urged. First: in the portions of Canada in which the glaciers in question are supposed to have originated we have reason to believe that the rocks are rounded and scratched, phenomena everywhere recognized as glacial,—but I think in no case characterizing rocks known to have been covered with perpetual snow. Again: the elevation and extent of the highest portions of Canada are hardly sufficient to account for the requisite accumulation of snow and ice. And finally, so far as I have learned, there is not found upon the rocks of the northern slope of Canada, nor yet in boulders moved by glacial force, any satisfactory evidence that there had been a northward as well as southward movement of glaciers from the highlands of Canada. If, therefore, the phenomena of the northern and eastern United States, usually supposed to be glacial, are indeed such, and if there is not sufficient reason for assuming the Canadian highlands to have been the source of the glaciers which produced these phenomena, then the source of them must be sought for elsewhere.
>
> I think it will be conceded by all geologists who have studied the glacial phenomena of these regions, that both the character of the erratics and the direction of the scratches upon the rocks show that this source must lie to the north-east. Following the line of the glacial movement across Baffin's bay and Davis straits to Greenland, we find the largest body of land in the northern hemisphere covered by ice and snow to a depth of not less than 2000 feet, and at this moment sending down its icebergs as far as the middle Atlantic. From the sixtieth degree of latitude to above the eightieth, this vast area of land is known to be ice-covered, and from the scarcity of the icebergs upon the eastern compared with the western coast of that land, it may be concluded

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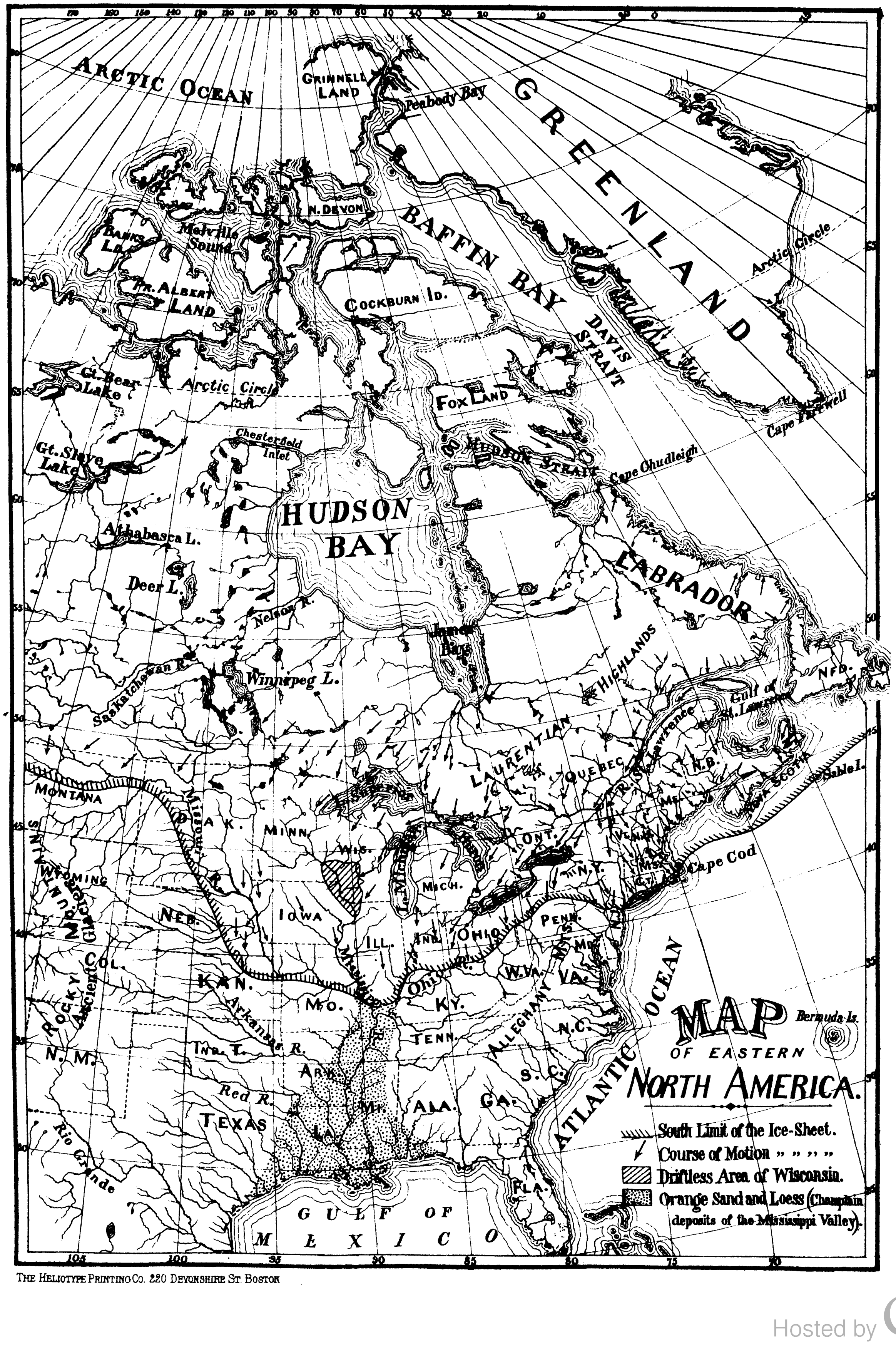
* *American Journal of Science*, iii, vol. xiii, p. 78.

that the general slope of the land is to the south-west, and in exact direction of the glacial markings of what is known to have been the course of the transported boulders in north-western America. Moreover, if we bear in mind the certainty that during the glacial period the glaciers moving from the height of Greenland towards the sea could not have formed detached icebergs as now, but must have for the time blocked up all avenues except the one of easiest escape for the immense accumulations of ice, we may easily assume this avenue was south-westward across British America and the north-eastern part of the United States.

Prof. Dana accepts this theory, saying that "we [self and Torell] agree in all essential points." A few suggestions have occurred to me, to the effect that the Greenland theory is untenable. (1) Accepting the notion that the ice moves as Croll proposes, on the molecular theory, there must be a piling up of ice to an enormous thickness, as much as twenty-two miles, to account for a motion from Greenland to the extreme south-west known limit of the ice-sheet. (2) The bridging of Davis straits seems very difficult to explain. The water is deep, and the straits or bay (Baffin's) wide, sufficiently so, it would seem, to discharge all the glacial products poured into it from either side. (3) Good instances of a northward transportation have been mentioned, the best known being northward from Hudson's bay. The great lack of observations of such a nature everywhere to the north of the Laurentian water-shed renders affirmation of their presence or absence valueless. Some have said that, on account of the cold, there would be little motion northerly. (4) The Labrador peninsula seems to me to offer a good situation for the accumulation of an ice-cap large enough to account for all the phenomena. The fiörds on the east indicate north-east movements of the ice; and three other courses have been mentioned, so that we find good evidence of motion in four directions from the central table land. Supposing this a centre, Greenland would have been a second, of equal or greater height, and the two would discharge their surplusage into the Atlantic. A cap of thirteen miles would be required for the thickness of this ice, if there were a flow from it to the western edges of the plains. (5) The growth of Greenland and the neighboring parts of the continent suggests the origin of the great basins, as of Baffin's bay, in Eozoic times, and a probable submergence ever since. The Hudson's Bay depression is similar (see Fig. 1, Vol. II). The Miocene deposits of Baffin's bay were made



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in the earlier formed basin, but did not fill it up. There was rather more subsidence, showing that the tendency in modern times has been to enlarge rather than restrict the size of the bay.

(6) The coldest part of the continent lies to the west and north of Hudson's bay. A comparison of meteorological tables given in various arctic expeditions indicates a greater average degree of cold in the west—say at Fort Reliance in Rupert's Land—than very far north. No greater degree of cold has been observed, but a lower average is reported for Greenland. For example: the lowest temperature indicated during the whole of one winter on the *Hansa*, which drifted along the entire east coast, was only —11° F. On the contrary, the average temperature for the four winter months,—December, January, February, and March,—for 1833–34, at Fort Reliance, as reported by Capt. Back, was —13°.9. For the winter ensuing, the average temperature for the same months was —21°.8. The Mackenzie valley, and the regions to the north-east, are noticed in meteorological treatises as remarkable for their cold. Being so very cold, the continental parts west and south-west from Greenland would be favorable for the preservation of ice in the summer, and thus for its accumulation in enormous sheets as time progressed.

MAP OF NORTH AMERICA.

I have prepared a small map of the northern part of the continent to illustrate the dispersal of the drift. Observations will be found recorded there, indicating the directions of the movements in all the states and provinces so far as known. Reference to it will save much time in description. There is also represented the southern limit of the ice-sheet, the driftless area of the north-west, and the boundaries of the territory occupied by the Champlain deposits, termed the "Orange sand," by Prof. Hilgard. All the geological reports of the several states, provinces, and territories, besides other volumes too numerous to be cited here, have been consulted for the preparation of this map, and it is believed to represent accurately the existing information respecting the dispersal of the drift. Where several courses have been described in a limited territory, only the predominant one can be given because of the smallness of the scale. Nor is the Rocky Mountain area delineated, since that belongs to a different centre of dispersion.

The facts seem to bear out the theory presented above of radial dispersion from the Labrador peninsula in all directions except west and north-west. Observations are wanting for that part of British America. There seem to have been three centres of dispersion for our continent when the ice possessed its maximum development: Greenland, Labrador, and the Rocky Mountains. There seems, also, to have been a movement of icebergs up the St. Lawrence valley, possibly coeval with the Orange sand deposit.

Cause of the Glacial Cold.

Various theories have been proposed to account for the reason of the very severe climate of the glacial period. First, was the view that earthquake-paroxysmal waves passed southerly over both continents. Second, came the iceberg theory, involving a submergence of over 6000 feet to explain all the phenomena. Third, the extreme glacial theory received much favor, where an elevation of the land was relied upon to produce the cold. If the land were extensively elevated, extreme cold would result, both because of increased cold in mountainous regions, and the deflection southerly of the warm oceanic currents. Both the iceberg and extreme glacial theories involve more extensive earth-movements than have appeared before in geological history, and hence do not fully commend themselves to general acceptance. There is no objection to the adoption of a modified glacial theory, such as has been advocated by A. S. Packard, Jr., where only 600 feet of elevation is called for to explain the phenomena.* Prof. Dana, in the last edition of his Manual, seems to accept a modification of the enormous elevation—5000 feet—advocated in the first edition, though he does not say how great an uprising of the land is called for.

The less extreme our theories, and the less the variation from existing conditions required by our suppositions, the nearer will be their approximation to truth. The following conditions probably existed, and by their combination brought about the extreme cold. 1. Elevation of land in the northern part of the continent for a few hundred feet, accompanied by the necessary partial withdrawal of the warm oceanic currents in both the Atlantic and Pacific oceans. 2. Coincidence of longer winters than summers, induced by precession of the equinoxes, with a period of great eccentricity of the earth's orbit. This might have been cited as a fourth theory of glacial cold, and has been abundantly presented earlier in the volume, page 5, *et seq.* The coincidence of these astronomical and physical conditions would be fully adequate to produce the intense cold. 3. Some authors add the existence of conditions favorable to the abundant precipitation of moisture in northern regions. Certain collateral conditions seem to have been connected with these, as, 4. The greatest accumulation of frozen moisture seems to have been about Labrador and Hudson's bay, whence it pushed outwardly in all directions, but mainly southerly, because that was the direction of least resistance. 5. The accumulation of several miles thickness of ice seem necessary in order to understand how motion could be induced. The land about Labrador is not so high as the mountains of New Hampshire, and we cannot reasonably assume such an enormous elevation of it as would be required to cause the flow over New England, or to the plains of Dakota. 6. The adoption of Croll's Molecular theory of ice-motion, or something similar to it, seems necessary. 7. The New England south-east movement probably resulted from the overflow of the St. Lawrence basin. The ice must have accumulated sufficiently to overflow the St. Lawrence-Connecticut water-shed before it could have moved over the White Mountains. 8. How extensive the earlier south-west movement over much of New England may have been is not yet determined. Only scanty traces of it remain.

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* *Memoirs Boston Society of Natural History*, vol. i, p. 260.

Inter-Glacial Deposits.

Messrs. Geikie and Croll insist upon the existence of warm periods in the midst of the long glacial winter sufficient entirely to melt the ice, and give rise to a succession of cold eons, alternating with the warm ones. Mr. Upham has already referred to the untenability of this position, page 7, and has described phenomena similar to those called interglacial by the Scotch authors (pp. 108, 131–137, 163, 164, 176, 290). It seems very clear that there are no phenomena in New Hampshire requiring us to accept the view of a succession of ice-periods. When the ice had once formed, it must have continued to rest upon the land until the removal of the eccentricity of the orbit restored the warmer conditions.

Two suggestions respecting the probable origin of all the inter-glacial deposits found in New Hampshire will not be out of place. 1. An explanation of Prof. Torell, of Sweden, is adequate to account for the example underneath the lenticular hill in New Ipswich,* and any other stratified beds in similar position. He represents that as the glacier commenced to exist and to move extensively, there must accumulate in favorable localities many stratified glacial deposits, so that a geological section of the edge of the ice would present (*a*) pre-glacial beds; (*b*) stratified glacial deposits; (*c*) a ground moraine; (*d*) the ice with its terminal moraine. Hence the advancing glacier may often cover stratified sandy deposits not of inter-glacial origin. 2. Our sections indicate that the stratified beds commonly occur between the lower and upper tills, as in Figs. 29, 32, 34, and 36. The Champlain fossils occupy the same position in the Portland section (Fig. 59). Assuming the correctness of our views regarding the origin of the two tills, all the inter-glacial phenomena are beautifully explained. It is not to be presumed that no variations in the position of the edge of the ice-sheet existed. The outer limit must have varied very much from time to time, just as it does at the present day in existing glaciers. When the ice retreated a few thousand feet, its melting would give rise to currents transporting sand. A change in temperature, or other conditions causing a readvance of the ice-sheet, would cause the stratified beds to be covered again, and the mass might even push a short distance over marine deposits at the ocean border. But no ground moraine made its appearance with this reädvance. No deposits were left behind except the débris contained in the ice itself, or upon its surface; and this fell to the ground during the melting process, and now remains as the upper till. This distinction between the tills has been lately recognized by English and Scotch authors. It also appears that the British inter-glacial beds occupy the same position with ours between the two kinds of till,† so that probably our explanation of the New Hampshire beds would fit the corresponding cases in Europe. In such case the name "interglacial" would still be applicable to them, although not in precisely the same sense in which the term is now understood. The preposition *inter* would signify a place between the two tills. These do not properly represent two glacial periods: they are different accumulations produced by a single ice-sheet, with a varying outer edge.

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* This is situated just south-west of Jeft's hill. By the side of the road an excavation shows about five feet of sand beneath the glacial drift, probably the lower till. The total thickness of the sand is not seen. In the overlying drift I observed a boulder of porphyritic gneiss four feet in length. Between this point and New Ipswich village the road cuts through a sand containing boulders, which is also probably underneath the glaciated till.

† "The till or boulder-clay that rests above these intercalated beds usually differs from the stony clay which

LENGTH OF THE GLACIAL PERIOD.

I desire to call attention to another feature of glacial history that has been overlooked. Granting that the cold period commenced 240,000 years ago, as determined by the orbital changes, it does not follow that it terminated 80,000 years since, when the extreme eccentricity disappeared. The conditions would have been analogous to the state of things observed every year in our climate. The extremest cold of winter does not occur at the shortest day, but fully six weeks later, while the snow may continue till the first of May, though usually disappearing by the middle of April, so the great glacial winter would not have terminated with the end of the cycle. The prodigious quantities of ice and snow covering the northern latitudes would not have allowed the return of spring for many thousand years. If we were authorized to compare directly the annual duration of winter after the shortest day with this glacial period, it would be possible to fix the date of the disappearance of the ice. About one fourth part of our year elapses between the winter solstice and the vernal equinox. A fourth part of the long glacial winter would be 40,000 years. This would bring the close of the glacial, or, better, the Champlain period, to an epoch 40,000 years ago. If there is any variation from this estimate, it appears as if the subsequent period would have been shorter rather than longer, because of the enormous quantity of ice to be melted.

The description of the events occurring in the Champlain period, such as the deposition of the kames and terraces, shows that the time of melting need not have been greatly prolonged. The kames, being laid down

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immediately underlies them in being less hard and tough. It is often sandier and more frequently contains very large blocks and boulders, while at the same time its included stones and boulders are not so universally well smoothed and striated—or, to express it otherwise, angular unpolished stones and boulders are more common in the upper than in the lower mass of till. Again, I may note that the intercalated beds often thin out so as to allow the upper and lower deposits of boulder-clay to come together."—Geikie's *Great Ice Age*, second edition, revised, p. 19.

in ice-walled ravines, could not have taken many years for their accumulation; and if the higher terraces are remnants of the immediately succeeding freshets, there is no reason to believe them long continued. Following out the analogy of seasons as already commenced, this should be compared with the spring freshets. These require very little time for their rise, culmination, and termination, while they may occur at successively later and later points of time, as you pass from the mouth to the source of the streams flowing southerly.

The time when man was introduced is connected with the figures assigned for the termination of the glacial period. There seems no likelihood that our ancestors would have found the conditions of life favorable to their existence among the glaciers, so that they would not have emigrated here from warmer latitudes before the Champlain period. No certain evidence of man earlier than the Champlain period has yet been discovered in any part of the world. Hence there is little reason to believe he was introduced more than 40,000 years ago.*

Recent Scotch authors insist upon a greater antiquity for man than this, because his implements have been found in the inter-glacial beds, thus carrying him back at least 100,000 years. The observations stated above intimate the unreliability of the theory respecting the great antiquity of these inter-glacial beds. Those in New Hampshire can all be accounted for without assuming the intercalation of warm periods into the glacial age. It would be ungracious to assume that our phenomena should be taken as the standard of measure for those elsewhere; but as very few other writers have perceived the distinction between the lower and upper till, we desire to be informed whether their inter-glacial beds cannot be referred to a place between the two kinds of drift, before accepting the Scotch conclusions. The use of astronomical calculations in the determination of the duration and definite place of the glacial period is of great importance, and if thoroughly proven will form a basis for the establishment of a geological chronology, not merely for the latter part of the Cenozoic, but of all time, even to the era of the Eozoön or the simpler denizens of the Eophytic period.

Mr. Upham has prepared some brief statements respecting the relative heights of land and sea during the glacial and Champlain periods. They are the result of much reflection upon his part, and are worthy of careful consideration.

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* This is given as the remotest possible date for the introduction of man. Other evidence might be presented illustrating the fact that very exaggerated notions of the great age of man prevail at the present day; but the subject has no connection with phenomena discovered in New Hampshire, and is therefore omitted.

CHANGES IN THE RELATIVE HEIGHTS OF LAND AND SEA DURING THE GLACIAL AND CHAMPLAIN PERIODS.

BY WARREN UPHAM.

Evidence has been found of the accumulation of immense ice-sheets, probably in the same epoch, over the north part of America, Europe, and Asia, also in New Zealand and the south part of South America. This points to some cosmical cause for the glacial period, like that assigned by Croll, rather than to the causes appealed to by Lyell and Dana, namely, elevations of the earth's crust. It would be a very improbable coincidence that such extensive regions surrounding both poles should be thus elevated in the same period; but these would obviously be the parts of the globe to be covered by ice if its origin was due to eccentricity of the earth's orbit. There seem to be reasons (pp. 7–9), however, to discredit the conclusion of Croll, that the ice-sheets were alternately wholly melted away in each hemisphere once in every 21,000 years; instead of which it seems probable that the ice-mantle existed upon both hemispheres at the same time.

The effect of this extraordinary accumulation of ice about the poles would be to take away a large amount of water from the ocean, and, furthermore, to draw the sea, by gravitation, away from the equator, leaving the sea-level lower than now within the tropics, but at the same time causing it to rise even higher than now near the lower limit of the ice-sheets, and much higher than now near the poles. Marine shells in the modified drift show that the sea thus rose 150 to 200 feet above its present height in the latitude of New York city; 500 feet in the valley of the St. Lawrence; and 1,000 to 2,000 feet in arctic regions. Everywhere in high latitudes, both in the northern and southern hemispheres, we have proof of such a submergence of the land when the drift was accumulated, increasing in amount the nearer we go to the poles. On the other hand, the coral islands of the tropics are witnesses of a depression of the sea, amounting to 3,000 feet or perhaps much more at the equator, while different proof shows that at the mouths of the Mississippi, Ganges, and

Po rivers it was at least 400 feet. If we reflect upon the widespread changes of sea-level that marked the glacial period, occurring only where they would be produced by taking water from the sea to form the ice-sheets, and by gravitation through their influence, and if we compare these recent simultaneous changes with the general stability of the continents, it seems reasonable to attribute them to movements of the sea rather than of the land.

In North America the southern edge of the ice-sheet varied from 38° to perhaps 50° north latitude. Nearly all of the continent north of this line, with portions of the sea next to the coast, the archipelago farther north, and much of the Arctic ocean, Hudson's and Baffin's bays, and Greenland, were probably covered by ice in the glacial period. This would be about one twenty-fourth part of the whole area of the globe. In the eastern hemisphere, Europe and Asia were apparently overspread by ice as far south, on the average, as to 50° north latitude. The North and Baltic seas, and a considerable part of the Arctic ocean, are to be added, making an area, as before, equal to about one twenty-fourth part of the earth. The glacial sheets of the antarctic continent and adjacent ocean, with Patagonia and its sea-border, were probably equal to each of the foregoing, so that in all about one eighth of the earth's surface was covered by ice. If a slope of one half of a degree is needed to cause the motion of these sheets of ice, an estimate of four miles for their average depth does not seem to be too great. The removal of the water thus taken from the sea and stored up in accumulations of ice would lower the surface of the ocean more than a half mile.

The effect of the ice-caps to draw the sea towards the poles remains to be considered. Because the ice was limited to high latitudes, its influence to raise the ocean over these areas would be much greater than if the same amount of ice had been spread in a thin covering, reaching, with gradually decreasing depth, to the equator. It may therefore be near the truth, to consider the effect in gravitation over glaciated regions to be the same as would result from an increase of the polar diameter by twelve miles of ice. This would be massed, as we have seen, in the proportion of two to one about the north and south poles, the greater part being accumulated in the northern hemisphere; still, the effect upon the sea-level would be nearly alike about both poles, in the same way that the moon produces two tides, one on the side next to it, and the other exactly opposite on the earth's surface. Now the specific gravity of ice, compared with that of the earth as a whole, is about as one to six. Therefore the ocean would be raised one mile at each pole, or nearly a half mile above its present height. At the same time, because all the ice was massed in high latitudes, it seems probable that everywhere within the tropics the sea would fall, through the influence of gravitation, below the depression of a half mile, which resulted from the removal of water to form ice.

These glacial sheets, when at their greatest extent and depth, caused the sea to rise 200 feet higher than now at Long Island, as shown by marine shells. At a somewhat later date, when the ice-front was retreating, the sea stood on the coast of New Hampshire and Maine 150 to 225 feet above its present level. Probably at this time so much of the ice northward had disappeared that this height does not correspond to that of 200 feet at Long Island; for we have evidence (in the sub-marine channel of Hudson river) that after the ice began to retreat, the sea-level at New York was depressed till it was at one time 600 feet or more below its present height. When the sea was elevated 200 feet upon the coast of Maine, or perhaps later, it stood 500 feet higher than now in the vicinity of Montreal and along the St. Lawrence valley. This somewhat greater height than we might expect seems to have resulted from proximity to vast depths of ice resting upon the highlands of Canada and Labrador. Near the middle of the Champlain period, when the ice-sheet over the northern United States and the south part of British America had principally melted away, but while immense ice-fields still lay farther to the north, the amount of water restored to the ocean would not probably raise it more than half of the whole amount that it had been depressed. At this time the tendency from gravitation to raise the sea-level at the latitude of New York would be small, and no longer sufficient, as when the ice-sheet had its greatest extent, to counterbalance the depression, so that the sea might stand 600 feet or more lower than now at New York, while the Hudson must form a channel now covered by the sea.

The testimony on this subject, which we have from Long Island and the submarine channel of Hudson river, may be summed up as follows:

When the ice-sheet over New York and southern New England melted, the sea stood, at least for part of this time, about 200 feet higher than now.* At this time the extensive plains of modified drift, forming the south side of Long Island and the submarine plateau that extends fully fifty miles south and south-west to the New Jersey shore, were deposited, being spread nearly level by the waves and currents of the sinking ocean. The valley of the Hudson river was also filled with modified drift to a height at Albany of 330 feet above the sea. The submarine channel proves that after this the sea-level was depressed at least 600 feet lower than now, while immense floods pouring down the Hudson valley excavated these deposits below our present sea-level from Albany southward. This channel at Haverstraw bay and the Tappan Zee is two to five miles wide. Its south-east portion with the areas on each side is now covered by the sea, but it is plainly traceable by soundings for more than a hundred miles south-east from New York bay.† This channel must have been excavated, as we have shown, after the melting of the ice-sheet over southern New England and New York, for otherwise it would have been filled with the modified drift which forms submarine plains on each side.

Although the deposition of modified drift seems to have ended in this region before the sea was thus depressed and this channel of the Hudson was formed, it still appears that very immense floods were discharged here. The ice had probably retreated from the most of New York state, and mainly from the basin of the great lakes, but still obstructed the St. Lawrence valley, turning a large part of the floods of this basin into the Mohawk and Hudson. This submarine channel thus appears to belong to the same epoch in which the beach-ridges about the great lakes were being formed.

At the east edge of the sketch map † representing this former extension of Hudson river, may be seen (south-south-east from Montauk point) the similar channel of Connecticut river in the same period, less notable than that of the Hudson, because the latter discharged vastly greater floods. A difficult point in our surface geology, which was before unexplained, is made clear by this depression of the ocean below its present level, following the departure of our part of the ice-sheet. In the first chapter of this volume it was shown that very large amounts of modified drift were excavated by the rivers in deepening their channels. Taking Connecticut and Merrimack rivers as examples, it seemed inexplicable, if the ocean from being 150 feet higher than now simply fell to its present level, to account for the disappearance of all the modified drift eroded between the upper terraces of these valleys. This explanation of the Hudson submarine channel is made more worthy of our belief because it also solves this difficulty. If the ocean was thus depressed, the modified drift excavated would be carried by the descending streams beyond our coast-line. W. U.

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* A bed of marine shells at this height in the modified drift of Long Island is described by Mr. Elias Lewis, Jr., in *Popular Science Monthly*, vol. x, p. 440.

† Dana's *Manual of Geology*, p. 441; new edition, p. 422; and *Popular Science Monthly*, vol. x, p. 444.

ORIGIN OF THE BLUE AND GRAY CLAYS.

In the first chapter (pp. 94, 153–155, and 158–161), Mr. Upham has brought together various facts respecting the distribution of the blue and gray clays overlying the till. He finds that the former invariably underlies the latter. This is true throughout New England, but not in the Western States, where alternations of the two kinds have been observed. The reason of this invariable order in the east has never been given satisfactorily. In order to contribute to the solution of this problem, I requested Mr. Upham to select for analysis typical specimens of the two tills and clays. Mr. G. W. Hawes presents the following as the result of their chemical examination. Only the iron percentages were determined:

	Upper till.	Lower till.	Gray clay.	Blue clay.
Iron protoxide, ...	1.42	1.75	2.75	3.17
Iron sesquioxide, ...	1.56	0.006	4.15	2.53

The tills came from Alton, the clays from Dover. The facts indicated are,—the proportionate increase of the sesquioxide of iron in the upper over the lower till, and in the gray over the blue clay; also, the clays contain more iron than the till. These facts are sufficient to explain the difference in color. They agree with the theory already propounded for the origin of the two tills,—that the first resulted as a ground-moraine from the pulverization of the rocks, and the second from the dropping down of all the materials in the ice-sheet at the time of melting. The upper deposit would be loosely aggregated and more highly oxidized than the lower beds, because the opportunities for the addition of oxygen were more favorable.

The very first question suggested by the position of the analyses is, whether the gray clay has not been derived from the upper and the blue from the lower till. The two classes of deposits agree in their chemical character, color, and superposition. I will advocate the affirmative answer to this question, and state how the conditions would favor such a derivation.

The blue clay is not continuous throughout the Connecticut and Merrimack valleys, but occurs in definite and limited areas, as has been set forth in Chapter I. Its origin may be conceived to be like that of similar clays near the mouths of glaciers. The water gathering from the various sub-glacial rills gathers the fine clayey material pulverized by the motion of the ice, and transports it to some lake or place of comparative quiet, and the sediment is deposited as a blue clay. In Hooksett and Pembroke is a mass of clay four miles or more long. Suppose that the glacier were still unmelted above Franklin, the pulverization of the rocks on the upper Pemigewasset would furnish an abundant supply of clay, which might have been transported to Hooksett before the current slacked sufficiently to allow the turbid water to settle. In this way the blue clay might have been formed, and it would have been derived altogether from the lower till. Subsequently, we may suppose, the ice began to melt more rapidly, and the detrital residue, or upper till, would be subjected to carriage. The first result would be the soiling of the streams with the more oxidized clay, and there would be formed the gray deposit over the blue. In the continuation of the process, the streams would become still larger, and the material brought down would be sand covering the gray clay; or the gray clay may be conceived to be the result of the washing of the upper terrace deposits. The finest particles in the case of a washing would be the first to show themselves low down the valley; and the material exposed is essentially the upper till.

This view explains how the formation of clay may be connected directly with the ice. The ice nearest the edge of the sheet, or on the ocean border, first melted, producing the upper till and a massive clay.

The next stage of the process would naturally be the deposition of blue clay, derived from the ice twenty or fifty miles away, and resting upon either of the tills where the glacier had once been present. When all the clays and sands had been supplied to the second area, the scene of action was transferred to a locality still nearer the ice, and so on till the whole had disappeared. Throughout the valley the clays overlie the till, although the stratified beds low down may have existed while the lower ground-moraine was forming among the mountains. The order of the conditions and of the deposits was strictly uniform, although at the present time it is difficult to realize that a clay at Newburyport should have been formed earlier than the same material at Hooksett. Some have imagined that no clay was formed till after the entire disappearance of the ice. In that case, we could not have had two kinds of clay. The waters washing away cliffs would mix together the protoxide and sesquioxide débris, and the resultant deposit would be unlike either of the beds now situated beneath the many brick-yards.

This view is in agreement with previously expressed suggestions about the rapidity of the accumulations of modified drift. The principal work of depositing the modified drift belongs to the epoch of the melting of the ice; and, following the analogy of spring freshets, the time must have been comparatively short, whether as compared with the antecedent glacial or the subsequent alluvial period.

Mr. Hawes expressed different views about the origin of these clays when the analyses were returned. I subjoin extracts from his letters:

> My interpretation of those analyses was something as follows: Finding *only iron protoxide* in the lower till, I thought the analyses indicated that, at the time of its deposition, the whole till contained iron only in the lower state of oxidation; that, being formed beneath the glacier by the grinding and pulverization of the rocks, it had no opportunities to oxidize. The upper till is lighter in color on account of the oxidation of its iron by the subsequent action of the atmosphere and percolating waters, which action has proceeded only to a certain depth. In being washed down into the valleys, a portion of the iron was oxidized,—and hence the *lower* clays contain iron oxide; and after the clays were deposited, the external agencies of air and water, acting on them as on the till, oxidized more iron in the superficial portion, making them again lighter in color than the lower clays. Thus the two colors of the till and of the clay are both referable to one cause,—the action of external agencies that have been in operation since the time of the deposition of these deposits, and are still in progress, driving the

dividing line deeper down. The fact of the presence of more iron in the clay than in the till is readily supposable, since iron is quite likely to be concentrated with the finest materials in the lowlands, leaving coarse pebbles behind. This, I think, answers all your questions, as I had understood the matter; but you will be the best judge as to the correctness of the suppositions.

The second letter is as follows:

In reference to the questions you propose in your last letter, you understand that I am unfamiliar with the field facts and the geological relationships involved, and so am not very able in my opinion. As I understand you, your opinion is, that the lower till was made from the clay derived from the grinding of the rocks by the lower surface of the glacier, and the upper till from the rubbish in and on the glacier, which was deposited on the melting of the glacier; and that subsequently the lower blue clay was derived from the lower till, and the upper gray clay from the upper till, by transportation by water; and you put the questions, "Could the lower blue clay have been derived from the lower till by deposition in water?" and "Could such material be transported without oxidizing the iron?" It does not seem to me that the lower clays could be derived from lower till, for if the washing took place after the deposition of the till, the strata of the till would be inverted in the clay beds, and the upper till would make the lower clay, since it would be the first to be transported by erosion. I do not think that material could be transported without any oxidation of ferrous compounds; but as the lower blue clay contains ferric oxide, this is not necessarily supposed. I incline to my former opinion of the production of an upper gray layer, in both cases, by those processes of oxidation,—by the external agencies that are everywhere going on in the rocks as well as soils. If, now, as is believed, the end of the glacial period was accompanied by great floods, and the latter end of the melting was rapid, the material in and through the glacier would not be deposited on the ground on top of the lower till, but would be washed away, and concentrated in the gravel beds. Clays in some cases may have resulted from the deposition of the finer portions, assorted by the rapidity of currents; but the material is usually coarse that rests on and in glaciers, and composed of broken fragments. The fine clay is that which is ground and pulverized by the lower surface grinding the underlying rocks. If, then, the till on the disappearance of the glacier was a substance uniform in composition from top to bottom, and of the same nature as the present *lower* till, then, by the action of running water, material from this bed might be transported to form clay beds without further oxidation of the iron than is shown by the difference between the lower till and lower blue clay. If the beds of both till and clay, as first deposited, were of the same nature as the lower beds at present, atmospheric and aqueous agencies would in time produce the differences in both now seen.

In speculating upon this subject, I was at first troubled by the somewhat similar origin of the upper till and blue clay, both in connection with water. Why should the former be so much and the latter so little oxidized? Relief came by examining the analyses. The blue clay contains more sesquioxide than the lower till, just as would be expected from the nature of the deposit. Furthermore, all blue protoxide clays have come from deposition in water;—hence there is nothing abnormal in believing in the origin of the lower clay from the older till.

Order of Events.

The following list of occurrences expresses our most recent opinions respecting the order of events occurring in New Hampshire in the Glacial, Champlain, and subsequent periods:

1. The country was covered presumably with forests of late Tertiary type, partly exhibited to us by the nearest fossils, yet of Eocene age, in Brandon, Vt. The beech, bass-wood, buckeye, Aristolochia, peperage, and cinnamon have been found there, with some others allied to the *coniferæ.* The change of climate induced by the change of land, combined with astronomical causes, would destroy most of these plants, and render the region sterile. Then the ice commenced to spread over New England, with alternate meltings of limited extent, so as to give rise to beds of sand and gravel.

2. The ice accumulated in the St. Lawrence valley so as to flow over New England, possibly preceded by a south-west current. The whole country would have been covered by a sheet of ice, thousands of feet in thickness,—probably 7,000 or 8,000 feet in the lower part of the state,—flowing south-east towards the ocean. This was the period of the formation of the lower till, and of the great terminal moraines of lower New England. The broad sandy plains of Cape Cod and Long Island mark the beginning of the Champlain period.

3. The melting of the ice has progressed steadily until no more ice is supplied from the St. Lawrence valley. New Hampshire is now covered by local glaciers, pushing down the Connecticut, the Merrimack, and other streams. The lower fossiliferous deposits of the coast are coeval with these glaciers. Variable seasons cause temporary advances and retreats of the ice, and thus allow of conditions favorable to the production of the inter-glacial beds.

4. The thermal influences prevailing, the ice is driven back to the

mountains; the débris which it contained forms the upper till; the kames show themselves, deposited between walls of ice; and the valleys are filled with plains of modified drift, including the blue and gray clays.

5. The terraces are produced by excavations of the last formed deposits; vegetation and animal life return; the horse and wild boar, whose remains have been found with us, flourished.

6. A warmer period followed, as illustrated by the presence of the rhododendron, cedar, and other plants upon the land; the quahog and oyster in the ocean, and the introduction of the American aborigines.

7. A somewhat colder climate, only a few hundred years back from the present date, ensued; New Hampshire was colonized by Europeans; and the present type of civilization has abolished the forest and exterminated the larger forms of animal life.

Notes on the Surface Geology of Coös County.

By J. H. Huntington.

Fluvial Deposits. These frequently have the appearances, as far as outline is concerned, of ordinary river terraces; but an examination of the material of which they are composed shows that they have an entirely different origin. In these the material is very coarse; and we often find boulders 8 or 10 inches in diameter. Usually they are not very extensive, and they are found only at the mouths of very rapid streams. The most extensive deposit of this is in Pittsburg, near the mouth of the stream which is the outlet of Back lake. Was all this coarse material, which occupies an area of many acres, brought down by the present stream? Mr. David Blanchard, who is well acquainted with the outline of the country, thinks that Perry stream once had its outlet here. The theory is very plausible, and there is little doubt but that such was the case. The barrier of rocks where the road crosses this stream, when it was a few feet higher than it is now, would have turned Perry stream into Back lake; thence it would have followed the course of the present outlet of that lake. Most of the drift that has been brought down by Indian and Hall's streams is of the same coarse material. Another deposit of this character is in the town of Stark along Nash stream. Almost every stream that comes down from high lands or mountains has brought down immense quantities of this kind of material, but nowhere to the extent that has been done in the localities just mentioned. How was this deposit formed? The present amount of water could not, even at times of the highest floods, have brought down this material and deposited it as we now find it. The resource to which we are led to explain this phenomena is this: At the time of the final retreat of the glaciers, just before they disappeared entirely, they were confined to the deep ravines of the high lands and the mountains. The melting of the glacier and the snow, with copious rains, for the moisture-laden currents coming in contact with these fields of ice would have been suddenly condensed,—all these would have had a tendency to produce floods that are now unknown.

Kames. The best examples of kames seen in Coös county are those which were formed as the glacier retreated from the valley of the Connecticut, in Columbia and Colebrook, and nowhere are they more striking than at Colebrook village. These are interesting, from the fact they show that for years the great glacier that filled the valley of the Connecticut here had its terminus. The fact that these gravel ridges do not appear above Colebrook shows that the change of climate was such as to cause the glacier to disappear rapidly when it receded above that point. The expansion of the valley at the village and just above, and its contracted limits below, were also causes that may have produced this phenomenon.

Erratics. There are very few but that have noticed, scattered through the fields, boulders unlike those of the rocks in the immediate vicinity. These boulders we call erratics or wanderers, because they have come from some distant place. Throughout northern New Hampshire, on account of the extensive tracts of forests, the study of all phenomena of drift is pursued under the most unfavorable circumstances, since in the forests there are no excavations, except that done by water along the streams. The boulders as well as the ledges are much more commonly covered with earth, or, at least, they are overgrown with moss, which has to be removed before we can tell anything about the rocks. To study thoroughly the geography of a country covered with forests, would, under most circumstances, be an endless task, although the area might be quite limited. On account of the fragile nature of many of the rocks in the extreme northern part of the state, boulders are not so numerous as in some other sections; and the absence of granite boulders is especially noticeable. North of Connecticut lake I do not remember to have seen but one granite boulder in all that area, and that was three or four miles east of Third lake. On Indian stream, eight or ten miles from its mouth, there were several boulders of conglomerate, and just north, three of brecciated iron ore. In Colebrook, near Mr. L. Dinsmore's, there is a conglomerate which is quite attractive even in hand specimens. None of these just mentioned were found in place, and where they came from is a matter of conjecture; but it is altogether probable that they came from Quebec province. Most of the boulders found in New Hampshire as far south as Columbia are derived from the hard bands in the argillaceous schist, or they come from the band of hornblende rock extending from Colebrook to the boundary. Everywhere south-east of this band, as far as Maine and even beyond the Magalloway, boulders of this rock are seen. As the rock is unlike any other, they are noticeable wherever they may be found; and they show that the general direction of the drift was considerably east of south.

In Stratford, just north of Little Bog brook, there is quite a remarkable collection of granitic boulders, both on account of the number and the limited area where they are found; besides, they must have come from Vermont, as granitic rocks of this kind are not found in New Hampshire.

In Errol, along the road to Upton, Me., we find an abundance of boulders of granitoid gneiss, which probably came from the vicinity of Wentworth pond. In Milan, particularly in the vicinity of Mr. Moses Hodgdon's, we find boulders of sienite that must have come from Mill mountain in Stark, or from the hill immediately north; consequently the drift here could not have been more than fifteen or twenty degrees south of east. There are two remarkable collections of boulders in the south part of Bean's Purchase, though they are derived, evidently, from ledges near where they are found. One of these is found a mile south from the summit of the Carter notch. The boulders are piled up so that they form a barrier across the valley, which is perhaps fifty feet higher than the depression towards the notch, in which there are two small ponds that have no visible outlet; but the water finds its way by an underground passage through the barrier, and where it issues from the rocks it forms quite a large stream. Above the barrier there are also many large boulders that have fallen down from the sides of the notch. Everywhere the boulders are angular, and their detachment from the ledges must have been quite recent.

Another remarkable collection of boulders is on the east branch of the Saco, a few miles east of the last mentioned. Here the rock is a gneissoid granite. The boulders are of immense size, and are scattered over an area of half a mile in width. They are everywhere covered with moss; and this supports a growth of firs, which are from eight to ten feet in height. Travelling is extremely difficult, both on account of the trees and the size of boulders. After a heavy rain, far down among the rocks streams of water flow, the existence of which would not be suspected if they could not be heard.

Lake Margins. The effect of the expansion of ice on our lakes, although noticeable in many places, is nowhere so marked as on the margin of Connecticut lake. At low water the rocks can be seen piled up in a wall-like structure, which on the south shore has a height of three or four feet, in places almost vertical. These rocks have been pushed a little year by year until they reached their present position, and were beyond the reach of ice-pressure. As the lake is now several feet above its natural level, a dam having been built at the outlet, if kept thus this wall will in time be removed to a higher level.

APPENDIX TO PARTS I AND II.

APPENDIX A.

DISTANT POINTS VISIBLE FROM MT. WASHINGTON.*

By W. H. Pickering.

IF an observer were to go up four particular peaks in the White Mountains he could see all the distant points visible from any of the other summits, together with a good many more not visible from them. These four peaks are Washington, Moosilauke, Passaconnaway, and Lafayette. I name them in the order of the extent of the distant views obtained from them alone. Now, looking at the subject the other way, no matter from what distant point the White Mountains are seen, one of these four points must always be the most conspicuous object in view, provided no near hills intervene. By means of the following formulæ the distance visible from any mountain may be readily calculated, and also the elevation a mountain must have in order to see a certain distance: $d = \frac{4}{3}\sqrt{h}$, $h = \frac{4}{7}d^2$, where $d =$ distance in miles, and $h =$ elevation in feet. They may also be used to calculate mountain profiles as seen from distant points. In this connection I may add that there is a slight inaccuracy in the Guide Book relating to Chocorua. It says,—"It is the noblest peak in all the view from Washington, and lifts its white pyramidal ledges far into the sky, flanked by bare supporting ridges." This must be a rhetorical hyperbole, for it is not at all true. And far from lifting its pyramidal ledges into the sky, it does not even come up to the level of the horizon by 420 feet.

For some time there has been a question whether Katahdin was visible from Washington or not. It is 163 miles distant, and would be the most distant point from which the White Mountains could be seen. According to calculation, 3500 feet of it should be visible if the land between were on the level of the sea. Now the horizon line as seen from Mt. Washington passes five or ten miles south-west of Moosehead lake. Moosehead lake has an elevation of 1023 feet above the sea. Now, allowing the land five or ten miles below it, measured on the river, to have an elevation of 1500 feet, Katahdin would still rise 1170 feet, and it would require an elevation of 2300 feet to hide it. Moreover, on remarkably clear wintry days, a very distant mountain has been seen in about the right direction, with a very peaked summit, which coincides with the descriptions of Katahdin. I should add, however, that as seen from Moosehead lake, which is in much the same direction, Katahdin does not present this appearance. It is claimed by some that Katahdin is visible from Kiarsarge; and there is a distant mountain visible from there on rare occasions, which I have seen once, but which is not in the right place. And, moreover, if there was an elevation between them of 390 feet above the sea, and near Mt. Blue, Katahdin would be hidden. Now, as all the country near Mt. Blue has an elevation of something over 1000 feet, it seems rather improbable that Katahdin should ever be seen. As to seeing it from Osceola, as some claim, one would have to look something like 100 feet below the sea horizon to see it.

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* Read before the Appalachian Mountain Club, October 11, 1876.

The following is a list of some of the more interesting distant points to be seen from Mt. Washington, many of them being visible only on rare occasions:

Mt. Belœil: distance 135 miles, position north 45° west, and nearly over Prospect hill, Lancaster. It is quite a high mountain near Montreal, and is said to be visible.

Lake Memphremagog: distance 70 miles, position north 40° west, and over Jefferson hill. It requires a very clear day, as distant water is difficult to distinguish.

Mt. Carmel: distance 65 miles, position north 10° east, and just over Mt. Adams. It is very near the northern boundary of Maine, and is readily recognized by the steep slope on the eastern side. It is said that a very fine view may be obtained from it.

Mt. Bigelow: distance 70 miles, position north 35° east, and nearly over Mt. Hayes. It appears as three rounded hills. Just to the south of it, and far beyond, is a mountain with a very sharp apex, which is sometimes called Katahdin, but this is a mistake.

Mt. Abraham: distance 65 miles, position north 40° east, and somewhat to the right of Mt. Hayes. A long serrated ridge, also sometimes called Katahdin.

Mt. Katahdin: distance 103 miles, position north 45° east, and about half way between Mt. Hayes and Mt. Moriah. It is said to appear rising over a nearer saddle-shaped mountain, and to be recognized by its sharp peak, the sharpest in all the view from Washington. If visible at all in summer, it would be far the faintest object in sight in that direction.

Mt. Blue: distance 57 miles, position north 57° east, and half way between Surprise and Moriah. It is quite a conspicuous pyramidal peak, and is near Farmington, Maine. It is used as a Coast Survey station.

Portland: distance 65 miles, position south 51° east, and over the northern summit of Doublehead. It appears as a low white hill, with a long light-blue line beyond it. With a telescope the hill resolves itself into a mass of closely packed white houses, and the blue line is seen to be thickly studded with sails. The ocean, however, is not as often seen as some more distant objects in other directions, partly on account of the difficulty of distinguishing distant water, and partly because the atmosphere in this direction seems generally to be somewhat thicker than elsewhere.

Lake Sebago: distance 43 miles, position south 48° east, and over Mt. Gemini. It is 14 miles long, and about 11 wide.

Mt. Agamenticus: distance 80 miles, position south 24° east. A flat rounded hill of considerable height in the southern part of Maine, and forms a conspicuous landmark for sailors.

Isles of Shoals: distance 97 miles, position south 22° east. They are very difficult to see, and are situated on the horizon just to the right of Agamenticus.

Mt. Wachusett: distance 126.5 miles, position south 13° west, and just to the right of Whiteface, if it is visible.

Mt. Monadnock: distance 104.5 miles, position south 22° west, and a little to the right of Sandwich Dome. A very regular rounded summit.

Mt. Kearsarge: distance 70 miles, position south 24° west, and half way between Sandwich Dome and Carrigain.

Mt. Uncanoonuc: distance 92 miles, position south 9° west, and half way between Mts. Crawford and Passaconnaway. Twin summits near Manchester.

Mt. Ascutney: distance 85 miles, position south 45° west. Situated in Windsor, Vermont, close to the Connecticut river.

Killington Peaks: distance 91 miles, position south 59° west, and between Mts. Liberty and Blue. Twin peaked summits near Rutland, Vermont.

Camel's Hump: distance 80 miles, position north 87° west, and just over Bethlehem street. It is a striking looking mountain, shaped like a truncated cone, with very steep sides. Readily visible at sunset on a clear day.

Mt. Whiteface: distance 130 miles, position north 86° west. It is just barely visible, hardly rising above the right hand slope of Camel's Hump. This is one of the highest of the Adirondacks, rising to a height of 4900 feet. Two lower peaks are seen just to the right, and three more some distance to the left. These however have not yet been identified, but if Mt. Marcy and any of the other higher summits are visible, they should appear about 7° to the south of Whiteface, and nearly over the Fabyan house.

Mt. Mansfield: distance 78 miles, position north 78° west, and between the Twin Mountain house and Mt. Deception. It is the highest of the Green Mountains, being 4300 feet high, and appears as a long ridge bearing a fancied resemblance to a human face.

APPENDIX B.

ALTITUDES, CONTOUR LINES, AND RAISED MAPS.

During all our explorations of the state for the study of its geology and the collection of rock-specimens, frequent barometric measurements have been also obtained, and the prominent topographic features of the country have been carefully noted. Only a small portion of all the heights thus measured appear in Volume I (pp. 210, 211, and 242, chap. x, and pp. 304–314), the altitudes there given being those of mountains, villages, ponds, or other points of special interest. Since the publication of that volume, many additional barometric observations have been made.

The information thus gathered respecting the configuration of the state, although incomplete because it has been impossible to make a detailed examination of our entire territory, yet seemed worth preservation, and sufficient to justify an attempt to present contour lines on the new map accompanying this report. Numerous series of altitudes, accurately determined by surveys for railroads, or by levelling done specially for the geological survey, have formed a basis to which the barometric measurements have been referred. According to these observed heights, and others estimated for adjacent hills and valleys, lines of contour for each one hundred feet above the sea were first drawn on the county maps of large scale, which had been used in our explorations, and thence were transferred to the draft of the new map. These lines have been engraved separately from the rest of the map, so that they may be printed in a color different from that of the streams, roads, boundary-lines, names, etc. They are thus easily distinguished from all other lines, but are required to be printed separately, so that they are liable to slight misplacement, sometimes making streams and contour lines disagree in their positions. These contours not only show the place, shape, and height of separate mountains and hills, but permit a comparison of their heights above the sea and in relation to each other throughout the whole state. For convenience in such comparison, the lines of 500, 1,000, 1,500 feet, etc., above the sea are dotted, and their heights frequently marked, while the other lines are continuous and unmarked.

The eastern part of Rockingham county, and the portion of Essex county, Mass., which comes within the limit of our map, being occupied more or less fully by the remarkable lenticular hills of glacial drift, have received special attention. Contour lines are shown upon these areas for each 50 feet, those marking heights 100, 200, and 300 feet above the sea being continuous lines, while those intermediate are dotted. The Ammonoosuc mining district has been surveyed by Mr. John N. McClintock, whose map with contour lines for each 10 feet is presented in Part V of this report. Besides these, the White Mountain district has perhaps been as well represented as any other portion of the state; but many of the smaller peaks, ridges, spurs, and ravines remain to be explored and mapped in this region. It is hoped that our efforts to show the form of the surface of New Hampshire by these lines will serve to call the attention of our people to the value of such work, and ultimately lead to a detailed topographic survey and map.

The same information respecting the altitude and contour of the whole state, which is shown by these lines on the maps in the atlas of this report, has been otherwise and more noticeably displayed by a model or raised map of New Hampshire, the original of which has been placed in the vestibule of the state-house at Concord. The museum of Dartmouth college has a copy moulded from this, and others might be easily made. It will be seen, however, that the construction of the first model, to show all our principal mountains, hills, and valleys, involves a large amount of painstaking labor. This relief has a scale of one inch to a mile in distance horizontally, and of one inch to 1,000 feet in height, making it about fifteen feet long, with Mt. Washington a little more than six inches high. The elevation is five times too great, as compared with the extent,—this exaggeration being necessary to give any prominence to the numerous hills less than 1,000 feet in height.

A map on the horizontal scale of the proposed model was first drawn, by enlargement from the draft of the new state map, with contour lines for each 500 feet above the sea. Tracings of these lines were then made and transferred to boards of pine or basswood half an inch in thickness, corresponding on the scale of height to 500 feet. The boards were then sawed to the irregular form of the successive contours. Upon each set of boards, the line next above that followed in sawing was also drawn, and showed the exact position to be occupied in placing them one upon another to build up the highlands and mountains. The projecting upper edges of the layers of board were then bevelled to a continuous slope, or cut into the hills and valleys required by intermediate lines of contour. The surface is painted, showing township lines, streams and ponds, railroads, etc., with their names, and those of villages and mountains.

In the study of the modified drift, a large amount of levelling has been done, principally along Connecticut and Merrimack rivers. The heights of all the terraces in both these valleys north of the Massachusetts line have been accurately determined, and are shown on Plates I–VI of this volume. Heights of these rivers and of localities near them were also determined, and are given, with the elevation of the highest terraces, on pages 39, 59–61, and 102 and 103. The most important corrections from altitudes along these rivers, published in Volume I, are in regard to the height of a portion of Connecticut river, which at Brattleborough is 200, at the mouth of Ashuelot river, 185, and at Massachusetts line, 180 feet above the sea (corrected from Vol. I, pp. 304 and 319); and the height of Pemigewasset river at the mouth of the east branch, which is 710 feet above the sea (corrected in this volume, p. 70, from Vol. I, pp. 288, 308, and 322). The height of Winnipiseogee lake obtained by levelling (pp. 103 and 125) suggests the possible need of a still more important correction to be applied to nearly all the connected series of altitudes determined by railroad surveys in the western and northern parts of the state, published in Chapter X of Volume I. These altitudes may be said to be reckoned from Concord depot as a starting-point, which appears upon good evidence to be 16 feet higher than was formerly supposed (see Vol. I, pp. 250–252). Referred to this datum, however, the height of Winnipiseogee lake appears to be 11 feet above that obtained by the survey for the Portsmouth, Great Falls & Con way Railroad (Vol. I, p. 265). One of these determinations of the level of the lake must be incorrect. Heights along Contoocook river and on streams in Antrim, with corrections to be made in Volume I, page 268, are stated in this volume on pages 102 and 119; heights along Salmon Falls river, on page 150; and in Dover, on page 156. Mr. George L. Whitehouse, of Farmington, informs us that the height given in Volume I, page 264, for the summit between Alton and Farmington, refers to the highest point of the railroad, while the greatest depth that would have to be cut through to turn Winnipiseogee lake into Cochecho river is only 28 feet, which calls for a correction on page 129 of this volume.

To the tables of altitudes previously published, we append a few additional observations, principally in the mountain region:

HEIGHTS IN THE WHITE MOUNTAIN DISTRICT.

From barometric measurement in 1876 and 1877 by Prof. F. W. Clarke:

On the Mt. Washington Range.

Nelson crag, north of Huntington's ravine, ...	5615
South wall of this ravine, . .	5432
Lion's Head, north of Tuckerman's ravine, ...	5016
Boott's spur, ...	5524
Foot of Mt. Adams path, . .	1430
Camp of Appalachian Mountain Club, Mt. Adams, ...	3307
First bald ledges on this path, .	4342
Cliff at head of King's ravine, .	5125
Summit of Mt. Adams (Guyot), .	5794
Samuel Adams peak, nearly ½ mile west, ...	5554
John Quincy Adams peak, ⅓ mile north, ...	5384
Nowell's peak, a little more than ½ mile north-west, ...	5313
Star lake, between Adams and Madison, ...	4890

Heights near Jefferson.

Starr King house, ...	1437
Mt. Starr King (Prof. C. R. Cross),	3925
Mt. Adams house, ...	1648
Boy mountain, ...	2278
Randolph hill, ...	1518
Jefferson Mills bridge, . .	1022
Bridge at Stag hollow, . .	1380
Israel's River bridge, Cherry Mountain road, ...	1085
Owl's Head, spur of Cherry mount.,	3302
Farmhouse at the foot of Owl's Head path, ...	1442
Bray hill, ...	1637
Mt. Prospect, Lancaster, . .	2062
Mt. Pleasant, " . .	1896
Road between these, . . .	1447
Farmhouse at the foot of path up Mt. Prospect, ...	1310
Summit of road from Jefferson to the Twin Mountain house, . .	1676
Lunenburg heights, Vt. (Prof. C. R. Cross), ...	1618

Heights in Bethlehem and Whitefield.

Sinclair house, ...	1459

Maplewood house,	1489
Dodge's, Whitefield,	1279
Fiske's, "	1250
On road from Whitefield to Bethlehem:	
Railroad crossing,	1109
Ammonoosuc bridge,	1119
Summit of road,	1305
Summit of stage-road by Mt. Agassiz,	1840
" upper stage-road from Bethlehem to Franconia,	1913
Wallace hill, Bethlehem,	2124

Heights near Franconia.

Summit of road between Littleton and Franconia,	1360
Bridge, Franconia Iron Works,	920
Lafayette house,	990
Franconia house,	1054
Profile farmhouse,	1302
Bald mountain,	2310
Notch on Lafayette path by Eagle cliff,	2990
Clearing between Profile and Flume houses,	1772
Moran or Lonesome lake,	2750
Summit of Sugar hill, Lisbon,	1895
Sugar Hill post-office,	1351

Ossipee Mountain, from a recent barometric measurement of Prof. C. R. Cross, is found to have a height of 2950 feet, instead of that given in Volume I, page 280. An eastern peak of this mountain is, by the same authority, 2774.

HEIGHTS IN CHESHIRE COUNTY.

In Section II, Volume I, page 284, correct the height of bridges in Swanzey by subtracting 550 feet.

From levelling by George W. Sturtevant, of Keene:

Goose pond, Keene, source of city water-works,	638

From levelling by J. J. Holbrook, of Keene:

Beech Hill reservoir,	595
Summit of Beech hill,	1060

Also from Mr. Holbrook's levelling, Troy station being taken as 1002 (Vol. I, p. 259):

Troy school-house No. 3, lowest step,	1166
Jaffrey school-house No. 12, threshold,	1231
John Mann's house,	1488
Monadnock Mountain house,	2072
Summit of Monadnock mountain,	3169

(Compare with Vol. I, p. 279).

From levelling by A. P. Little, of Keene:

Swanzey, Sawyer's crossing, R. R. bridge,	485
West Swanzey, railroad, 495; Ashuelot river above dam, 461; below dam,	454

APPENDIX C.

APPENDIX TO THE CATALOGUE OF THE PLANTS OF NEW HAMPSHIRE.

The number of plants known to grow without cultivation within the limits of the state has been somewhat increased since the publication of Volume I. These additions to the catalogue of that volume (pp. 395–414), together with those found in its appendix, are here presented, marked with letters and signs which are there used and explained, indicating distribution, relative abundance, and introduced species.

A paper on the "Distribution of Plants in New Hampshire and Vermont," by William F. Flint, occurs in the *American Naturalist*, Volume XI, pages 89–95. The flora of the White Mountains has been described by Edward Tuckerman, in T. Starr King's *White Hills*, pages 230–241; and by J. H. Huntington in *Appalachia*, Volume I, pages 100–106.

POPPY FAMILY.

Papaver Rhœas. Corn Poppy.
Hanover.

MUSTARD FAMILY.

Dentaria maxima.
Near Bedell's bridge, Haverhill.

Arabis perfoliata.
Fields along Connecticut river.

A. Drummondii.
Island in Connecticut river near White River Junction.

PINK FAMILY.

Cerastium vulgatum.

Spergularia media. . . . . . S

VINE FAMILY.

Vitis cordifolia; var. riparia.

MILKWORT FAMILY.

Polygala cruciata. . . . . . *
Near the coast.

PULSE FAMILY.

Colutea arborescens.

Astragalus alpinus.
A. Robbinsii.
Growing together at Sumner's Falls, Plainfield.

Vicia tetrasperma.

ROSE FAMILY.

Prumus maritima. Beach Plum. . *
Near the coast; also on the upper terrace west of Amoskeag falls.

Poterium Canadense. Burnet. . . *
Near the coast.

Pyrus arbutifolia; var. erythrocarpa.
var. melanocarpa.

SAXIFRAGE FAMILY.

Mitella nuda.
Hanover.

WATER-MILFOIL FAMILY.

Proserpinaca palustris. Mermaid-weed.

LOOSESTRIFE FAMILY.

Lythrum Hyssopifolia. . . . S

PARSLEY FAMILY.

Ligusticum Levisticum. Lovage.
Around old dwellings.

Zizia integerrima.

HONEYSUCKLE FAMILY.

Lonicera parviflora.
Connecticut valley.

COMPOSITE FAMILY.

Eupatorium teucrifolium.

E. pubescens.

Sericocarpus solidagineus.

Aster tenuifolius.

A. carneus.

A. Novæ-Angliæ.

Solidago stricta.

S. patula.

Ambrosia trifida.

Bidens bipinnata.

Anthemis arvensis. Corn Chamomile.

Artemisia vulgaris. Mugwort.

Onopordon acanthium. Scotch Thistle.

Cynthia Virginica.

HEATH FAMILY.

Leucothoë racemosa. . . . . . *
Near the coast.

Chimaphila maculata.
Seabrook.

Pterospora Andromedea. Pine-drops.
Hanover.

BLADDERWORT FAMILY.

Utricularia purpurea.
Winchester.

U. resupinata.

Pinguicula vulgaris.
Mt. Willard.

BROOM-RAPE FAMILY.

Aphyllon uniflorum. Cancer-root.

FIGWORT FAMILY.

Veronica peregrina.
Fields in Connecticut valley south of Bellows Falls.

Gerardia purpurea. . . . . . *
Near the coast.

G. maritima. . . . . . . *S*

MINT FAMILY.

Monarda fistulosa. Wild Bergamot.
Rockingham county.

Galeopsis Ladanum.
Hanover to Hinsdale; rare.

GENTIAN FAMILY.

Gentiana quinqueflora.
Hanover.

Bartonia tenella.

DOGBANE FAMILY.

Apocynum cannabinum; var. hypericifolium.

AMARANTH FAMILY.

Amarantus hypochondriacus.

A. spinosus.

BUCKWHEAT FAMILY.

Rumex salicifolius. White Dock. . *S*

R. maritimus. Golden Dock. . . *S*

OAK FAMILY.

Quercus bicolor. Swamp White Oak.
Low'r Merrimack valley and Rockingham county.

Q. Primus; var. humilis. Dwarf Chinquapin Oak.
Same range as the last.

WILLOW FAMILY.

Salix tristis.
Lower Merrimack valley.

S. nigra; var. falcata.

PINE FAMILY.

Cupressus thyoides. White Cedar.
Manchester, and near the coast.

ARUM FAMILY.

Peltandra Virginica. Arrow Arum.
Walker's pond, Conway.

DUCKWEED FAMILY.

Lemna polyrrhiza.

CAT-TAIL FAMILY.

Sparganium simplex; var. androcladum.

ORCHIS FAMILY.

Spiranthes Romanzoviana.
Bogs; New Hampton.

Pogonia pendula.
Winchester.

IRIS FAMILY.

Iris Virginica. . . . . . . *
Near the coast.

RUSH FAMILY.

Juncus militaris.

SEDGE FAMILY.

Eleocharis pygmæa. . . . . . *S*

Scirpus polyphyllus.

S. lineatus.

Rhynchospora capillacea.

Carex siccata.

C. Emmonsii.

C. Kneiskernii.

C. polymorpha.

C. Houghtonii.
Franconia.

GRASS FAMILY.

Calamagrostis Nuttalliana.
Hampton.

Spartina cynosuroides.

Poa cæsia.
Summit of Mt. Willard.

Bromus Kalmii.

Hierochloa borealis.
Hanover and Amherst.

Panicum virgatum. . . . . . *
Near the coast.

P. pauciflorum.

HORSETAIL FAMILY.

Equisetum scirpoides.
Along Connecticut river.

CLUB-MOSS FAMILY.

Isoetes echinospora; var. Braunii.

I. riparia.

CATALOGUE OF THE MOSSES AND LIVERWORTS OF NEW HAMPSHIRE.

The nomenclature is that of Sullivant's *Musci and Hepaticæ*, from which the species found upon the White Mountains (designated by M) are compiled. The others have been collected in the vicinity of Hanover by William F. Flint and Edward Hyde, or in the south-west part of the state by Charles C. Frost, the distinguished cryptogamic botanist, of Brattleborough, Vt. Commonness is indicated by a star (*).

MOSSES.

Sphagnum cymbifolium. . . . *
S. Lescurii.
S. sedoides.
Ethan's pond.
S. squarrosum. . . . . . *
S. acutifolium. . . . . . *
S. cuspidatum. . . . . . *
Andræa rupestris. . . . . M
A. crassinervia. . . . . . M
Phascum serratum.
P. cuspidatum.
P. Sullivantii.
Gymnostomum curvirostrum. . . *
G. rupestris. . . . . . *
Weisia viridula. . . . . . *
Rhabdoweisia fugax. . . . . M
Arctoa fulvella. . . . . . M
Dicranodontium longirostre.
Trematodon longicollis. . . . *
Dicranum gracilescens; var tenellum. M
D. varium. . . . . . . *
D. rufescens. . . . . . *
D. subulatum. . . . . . M
D. heteromallum. . . . . *
D. Blyttii. . . . . . . M
D. Starkii. . . . . . . M
D. flagellare. . . . . . *
D. interruptum.
D. longifolium.
D. scoparium; var. pallidum. . . *
D. undulatum.
D. Drummondii. . . . . M
Ceratodon purpureus. . . . *
Leucobryum glaucum. . . . *
L. minus.
Fissidens minutulus.
F. bryoides.
F. osmundiodes. . . . . *
F. subbasilaris.
F. taxifolius.
F. adiantoides. . . . . . *
Conomitrium Julianum.
Trichostomun pallidum. . . . *
Barbula unguiculata. . . . . *
B. cæspitosa. . . . . . *

B. convoluta.	*
B. mucronifolia.	*
Pottia truncata.	
Tetraphis pellucida.	*
Tetrodontium repandum. Near the Glen house.	
Encalypta ciliata. Hanover.	
Zygodon Lapponicus.	M
Z. Mougeotii.	M
Drummondia clavellata.	*
Orthotrichum obtusifolium.	
O. strangulatum.	*
O. Canadense.	*
O. Ludwigii.	*
O. Hutchinsiæ.	*
O. crispum.	*
O. Bruchii.	M
Ptychomitrium incurvum.	
Schistidium apocarpum.	
S. confertum, var.	M
Grimmia Olneyi.	*
G. Pennsylvanica.	*
G. Donniana.	M
Racomitrium aciculare.	*
R. lanuginosum.	M
R. fasciculare.	*
R. ellipticum, Br. and Sch.	*
R. canescens.	M
Hedwigia ciliata.	*
Diphyscium foliosum.	*
Atrichum undulatum.	*
A. angustatum.	*
A. crispum.	*
Pogonatum brevicaule.	
P. urnigerum.	M
P. capillare.	M
P. alpinum.	M
Polytrichum commune.	*
P. formosum.	
P. juniperinum.	*
P. piliferum.	*
Aulacomnion heterostichum.	*
A. palustre.	*
A. turgidum.	M
Bryum pyriforme.	*
B. crudum.	M
B. nutans.	
B. cucullatum.	M
B. roseum.	*
B. Wahlenbergii.	*
B. argenteum.	*
B. pseudo-triquetrum.	
B. alpinum.	M
B. bimum.	*
B. capillare.	*
B. cæspiticium.	*
Mnium affine.	*
M. hornum.	M
M. stellare.	*
M. cinclidioides, Hedw.	
M. punctatum.	*
M. Drummondii.	M
M. rostratum.	*
M. cuspidatum.	*
M. spinulosum.	M
Meesia uliginosa.	M
Bartramia ithyphylla.	M
B. Oederi.	
B. pomiformis.	*
B. fontana.	*
Conostomum boreale.	M
Funaria hygrometrica.	*
Physcomitrium pyriforme.	*
Tetraplodon angustatus.	M
Fontinalis antipyretica.	*
F. Eatonii, Sulliv.	*
F. disticha. Saco river in White Mountain Notch.	
F. Lescurii.	
F. Frostii, Sulliv.	*
F. Dalecarlica.	M
Dichelyma falcatum.	*
D. capillaceum.	*

Leucodon julaceus.	*
Leptodon trichomitrium.	*
Anomodon viticulosus.	*
A. tristis.	*
Leskea obscura.	*
L. rostrata.	*
L. nervosa.	M
Clasmatodon parvulus.	
Thelia hirtella.	*
T. asprella.	*
Anacamptodon splachnoides.	
Palaisæa intricata.	
Homalothecium subcapillatum.	*
Platygyrium repens.	*
Pterigynandrum filiforme, Hedw.	*
Cylindrothecium cladorrhizans.	*
C. seductrix.	*
Neckera pennata.	*
N. bifida, James.	
White Mountain Notch.	
Omalia Jamesiana.	M
Climacium Americanum.	
Hypnum tamariscinum.	*
H. delicatulum.	*
H. scitum.	*
H. abietinum.	*
H. paludosum.	*
H. triquetrum.	*
H. brevirostre.	*
H. splendens.	*
H. umbratum.	
H. Oakesii.	M
H. Allegheniense.	*
H. strigosum.	*
H. serratulum.	*
H. rusciforme.	*
H. recurvans.	*
H. demissum.	
H. cylindricarpum.	*
H. eugyrium.	M
H. palustre, L.	*
H. ochraceum.	M
H. montanum.	M
H. cuspidatum.	*
H. Schreberi.	*
H. cordifolium.	*
H. stramineum.	*
H. uncinatum.	M
H. fluitans.	*
H. aduncum.	
Ethan's pond.	
H. Crista-Castrensis.	*
H. cupressiforme.	*
H. imponens.	*
H. reptile.	*
H. curvifolium.	*
H. Haldanianum.	*
H. nemorosum.	
H. pratense.	*
H. salebrosum.	*
H. lætum.	*
H. rutabulum.	*
H. plumosum.	*
H. populeum.	*
H. reflexum.	M
H. Starkii.	M
H. Novæ-Angliæ.	
H. stellatum.	*
H. polymorphum.	*
H. hispidulum.	*
H. dimorphum.	
Ellis river.	
H. subtile.	
H. adnatum.	*
H. serpens.	*
H. radicale.	*
H. orthocladon.	*
H. riparium.	*
H. Lescurii.	
H. denticulatum.	*
H. Muhlenbeckii.	*
H. sylvaticum.	*

H. elegans.	M

LIVERWORTS.

Riccia natans.	*
R. fluitans.	*
Anthoceros punctatus.	*
A. lævis.	*
Marchantia polymorpha.	*
Fegatella conica.	*
Reboulia hemisphærica.	*
Fimbriaria tenella.	*
Mentzgeria furcata.	*
Aneura palmata.	*
A. multifida.	
Pellia epiphylla.	*
Blasia pusilla.	*
Chiloscyphus polyanthos.	*
Lophocolea bidentata.	
Sphagnœcetis communis.	*
Jungermannia trichophylla.	*
J. setacea.	*
J. connivens.	*
J. curvifolia.	*
J. bicuspidata.	*
J. divaricata.	*
J. setiformis.	M
J. barbata.	*
J. intermedia.	*
J. Schraderi.	*
J. Taylori.	
J. crenulata.	*
J. exsecta.	*
Scapania nemorosa.	*
Plagiochila spinulosa.	*
P. asplenioides.	*
P. porelloides.	*
Sarcoscyphus Ehrharti.	*
Gymnomitrium concinnatum.	M
Frullania Grayana.	*
F. Tamarisci.	*
F. Virginica.	*
F. Eboracensis.	*
Lejeunia cucullata.	*
Madotheca platyphylla.	*
Radula complanata.	*
Ptilidium ciliare.	
Trichocolea Tomentella.	*
Mastigobryum trilobatum.	*
Lepidozia reptans.	*
Calypogeia Trichomanis.	*

APPENDIX D.

THE RELATION OF GEOLOGY TO DISEASE.

By G. W. Hawes.

Mr. J. T. Gardner, in his address before the American Public Health Association at Boston,[*] has drawn attention to the intimate connection between geology and health. He indicates that controlling causes of some of our most fatal diseases are to be found in local structural and lithological conditions, which are of even greater weight than the condition of the air. In some regions above the palisades of the Hudson malarial diseases are very prevalent. This region is underlaid by dense basaltic rocks, through which water cannot percolate, but is accumulated in basins beneath the surface, there to become stagnant and breed disease in a high region which has pure clear air and apparently all the conditions for the best of health. Many cases are cited; among which is one of interest to us, as it shows that considerations of this kind are worthy of closest attention in New Hampshire. The case is derived from the study of the geological conditions in the town of Greenland, N. H., and is quoted from an article by Dr. Henry I. Bowditch on "Consumption in New England, and locality one of its chief causes."

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[*] Boston, October 6, 1876.

Dr. Bowditch thinks that the most powerful agent in promoting the disease called consumption is the soil moisture which results from the structure of the country and the character of its soil and underlying rocks. In Greenland there are three distinct varieties of soil:—1. A high and dry sandy plain. 2. A middle fertile and rather moist portion. 3. Extensive low marshes. Between these three portions the inhabitants, 715 in number, were about evenly divided; and yet, in a given length of time, there were three deaths by consumption on the sandy plains, five in the middle moist region, and ten in the lowlands, or three times as many in the wet as in the dry region. But in a town in Maine the conditions were exactly reversed: the *lowlands* were of porous gravel, while the highlands were clayey and impervious to moisture. Here, in a given length of time, the number of deaths was two times larger on the *highlands* than on the lowlands.

These cases indicate that the character of the rocks, and their mode of arrangement, are important elements in the control of health or disease, and that the character of our rocks and the mode of arrangement, which have been described at such length in these volumes, have an important influence on the duration of human life. They indicate that the crystalline condition, the schistose or compact structure, the geological arrangement of rocks, and all those characters of rocks and soils which facilitate or impede drainage, are powerful influences in determining local conditions for health, and that, therefore, the lithology and geological structure of their special region should be a study of each member of the medical profession.

APPENDIX E.

NOTE ON SOME POINTS IN THE GEOLOGY OF STODDARD AND MARLOW, CHESHIRE COUNTY, N. H.

By Sanborn Tenney.

The prevailing rocks in this region are gneissoid and mica slate. Their strike is north-easterly, being north 30°–40° east by the needle, and they dip easterly at a high angle, in many places 60° or more. In some places, as near Stone pond, in Marlow, the bedding is exceedingly well defined, so that the effect is very beautiful, especially as dark and light colors alternate more or less with one another.

The whole region gives the most ample evidence that it was once subjected to long continued glacial action. The rocks are planed down and grooved, and boulders in many places almost cover the ground over areas miles in extent. Probably there are but few places, if indeed there are any in our country, where the boulders are more numerous than in this part of New Hampshire. Between Hancock and Marlow, inclusive, the boulders are, in a great majority of cases, porphyritic granite. In the vicinity of South Stoddard, some of the boulders are of enormous size. One boulder, not far from the road, and on the right hand in going from the "Box tavern" to Stoddard village, is about fifty paces in circumference, and probably contains 40,000 cubic feet of rock. Many others in the vicinity approximate this in size. Another of very great size is found about half a mile from the village of Marlow, in a southerly direction, and just east of the Ashuelot river.

Rocking-stones are not uncommon in this region. Two beautiful examples of this kind are found in Marlow, not far from a place in the Ashuelot river well known as the "Bend." Several of these stones are found on a hill westerly from the Abbot pond, which is on the right hand of the main road leading from Stoddard to Marlow. But I hasten to say that not one of these last will now "rock," for they have been tipped and wedged up by stones, put in by the farmers, as I learned, under the impression that the flocks and herds might be injured by them. I believe that an ox, or some other creature of the farm, did get caught by the tipping of one of these boulders, and this fact led to the wedging of them so that they could not rock. We examined them, and satisfied ourselves that they would rock again as soon as these props or wedges were removed.

The drift striæ in Marlow are nearly due north and south, varying only slightly from a due northerly and southerly course, as the needle points. The effect produced by the planing down of the highly inclined slate near Stone pond is very interesting and beautiful. Not a projecting point is left, and the bare, clean, and smoothly planed edges of the dark- and light-colored layers of the gneissoid rocks present a very striking and beautiful appearance to the eye of the geologist.

Very near the outlet of Stone pond are very beautiful examples of granite dykes in the gneissoid rocks, some crossing others, and thus showing that they were formed at different times. Northerly from Stone pond, at a distance of a mile or less, is Trout pond, interesting from the fact of its being nearly surrounded by high hills of drift. One large moraine is, as it were, cut off by the pond; the moraine continues for a considerable distance northerly and southerly, interrupted only by this pond. How this pond was formed in the line of this moraine, is an interesting question. Was the pond there before the moraine? If so, why was it not filled by the drift material? Is it not probable that the age of the pond dates from the glacial period, and that there was a vast accumulation of ice just where this pond is to-day?

APPENDIX F.

GEOLOGY OF THE REGION ABOUT THE HEAD WATERS OF THE ANDROSCOGGIN RIVER, ME.

BY J. H. HUNTINGTON.

If we examine a map, and look at the western part of New Hampshire, we see that Hall's stream, one of the principal branches of the Connecticut river, has a part of its branches in the province of Quebec; then eastward, all the streams as far as the St. John's in Maine have their waters wholly in the states. Of the streams included in this area, Indian, Perry's, the Connecticut, the Magalloway, the Cupsuptic, the Kennebago, Dead river, and Moose river, I have followed from their sources to their confluences with other waters; and, besides this, I have traversed much of the intervening country. As a continuous forest extends along the north-western border of Maine, geological work is slow and extremely laborious. The topography of the country is somewhat peculiar. The boundary itself is a mountainous ridge, rising from 2,500 to 3,000 feet above the sea, and it is extremely irregular in outline. The streams from Hall's to Dead river have a course almost due south; then to the north-east the streams at first all begin their courses by flowing northerly and north-easterly. The glaciation of the continent, and the trend of the strata of the rocks, have given in part, at least, this peculiar feature to the streams of this region, though there is no doubt but that the great depression of the St. Lawrence valley is the primal cause.

The area of country to which this paper relates more specifically borders on the Cupsuptic and Kennebago rivers. Both of these streams rise on the boundary. On the first, three fourths of a mile from the boundary, the beavers, by building a dam, have formed quite a little lake. This is 600 feet below the highest point of the ridge. For five miles in a direct line the stream is sluggish, and is frequently interrupted by beaver dams; then for half a mile it cuts a deep gorge through an argillaceous schist, and has a fall of some thirty feet; then for six or seven miles it has very much the same character that it has above the gorge; then for nearly a mile it rushes along in a series of wild cascades, while here and there it plunges down into great eddies, when it rests only to leap again over the rocky strata below. The falls passed, it assumes again its sluggish character, which it retains until it flows into Cupsuptic lake. The entire length of the stream in a direct line is about 13 miles. The Kennebago is quite a different river. On the boundary rise numerous streams, which widen into lakelets, and then flow southward until they unite in No. 4 R. 3. Then the descent is quite gradual until after it passes Kennebago lake,—then there are extensive falls; thence for the most part the descent is gradual for the rest of its course. There are some things about the topography that are quite noticeable. From a point a mile south of the outlet of Kennebago lake a range of mountains begins, which runs north-west, and extends to the

Cupsuptic. On the Kennebago, the rock is fissile slate; on the Cupsuptic, the rock is an argillaceous schist; but the summit, at least of the north-west peak, is granite. From the point where the streams unite in No. 4 R. 3, a range of mountains on the west side of the Kennebago runs north-west; and on the east side of the river a range runs north-east. Between these ranges are the streams mentioned above as widening into lakelets.

The area about the lakes was briefly mentioned by Prof. C. H. Hitchcock in the report of the scientific survey of Maine for 1862.

The conglomerate found at the outlet of Rangeley lake has been described by Prof. Geo. L. Vose. Some notes on the geology of the area north-east of Kennebago river were presented at the Portland meeting of the American Association for the Advancement of Science. The rocks found on the west of the Cupsuptic have been described by me at some length in the report of the geological survey of New Hampshire (Vol. II). As I understand the rocks, the following formations are represented:

I. Stratified Groups.

Laurentian.	Gneiss.
	Gneiss containing limestone.
Huronian.	White Mountain gneisses and schists.
	Mica schists with staurolite.
	Chloritic and whitish argillitic mica schists.
	Sandstone schists.
	Diabase.
	Diorite with serpentine.
	Argillitic mica schist with staurolite.
	Rangeley conglomerates.
Paleozoic.	Wrinkled argillaceous schists with hard micaceous bands.
	Slaty conglomerates.
	Calcareous sandstones with fossils.
Cenozoic.	Glacial drift.
	Modified drift, including kames, etc.

II. Eruptive Rocks.

Granite (Conway).
Diorite.
Felsite.

Gneiss. The area of gneiss is very small, and it was seen only on the boundary on the head waters of the north-west branches of the Kennebago river. It is a fine-grained rock, and the outcrops were so few that the dip could not be well determined. As an intrusive granite and a fine-grained diorite were the only rocks seen in the vicinity, its stratigraphical relations have not been satisfactorily determined; but its resemblance to the Laurentian gneiss in the vicinity of the chain of lakes to the north-east makes it altogether probable that it is a part of the Upper Laurentian.

Gneiss with Limestone. Approaching the lake region from the east at the village of Phillips, we find an intrusive granite that is somewhat coarser than the common Concord granite. It extends a mile east of the village. On Sandy river, where the road crosses the river for the first time above Phillips, we find the intrusive character of the rock clearly seen, as here great masses of schist have been caught in it; and elsewhere the granite appears only as veinstones in the schist. About two miles above the village, on the north side of the river, there is a fine-grained micaceous gneiss that has intercalated beds of a dark limestone: this at some time has been burned for lime. The whole breadth of country occupied by this gneiss does not here exceed a mile. The stratum is very irregular in strike, and has an inclination of 30° to 50°.

Huronian—White Mountain Gneisses and Schists. These rocks, which belong to the Montalban series of the New Hampshire geological survey, are found north-west of the outlet of Moosetocmaguntic lake. The strata here have nearly an east and west strike, and are vertical; but this is probably due to a great mass of intrusive granite between this and the river that joins the lakes on the south. The lithological character of the rock is similar in every respect to the rocks found in the vicinity of Mt. Washington, and it is probably a continuation northward of the rocks so extensively developed along the Androscoggin river in Gorham, N. H., and eastward. This is near the northern limit of these rocks in the area we have studied.

Mica Schists with Staurolite. South of Moosetocmaguntic lake, in townships D and E, and extensively developed in the town of Byron, is a series of rocks consisting of fine-grained, thick-bedded mica schists that carry staurolite. These schists, wherever observations were made, have a dip almost directly north; and the inclination does not usually exceed 45°, especially northward. From the south, they follow directly on the White Mountain gneisses.

Chloritic and Whitish Argillitic Mica Schists. North of the rocks last mentioned, and east of the White Mountain gneisses, near the northern part of Moosetocmaguntic lake, and extending east beyond the outlet of Rangeley, there is a series of rocks consisting chiefly of chlorite and whitish argillitic schists. They are noticeable on account of their unconformability with the rocks east and south, and the abundance of quartz which they contain, and which lies in the line of the stratification. This rock forms ledges at Frye's Camp, at Houghton's Camp, and on the ridge immediately south of the Mountain View house at the outlet of Rangeley lake.

Bald mountain, an isolated peak between Rangeley and Moosetocmaguntic lakes, although chiefly granite south of the ridge just mentioned, has upon its top a great mass of this schist, which was caught in the granite. Indian Rock, at the mouth of Kennebago river, and famed in the annals of fishermen, is a wonderfully contorted argillite, and may possibly belong to a different series of rocks. The hill immediately north of Cupsuptic lake is a light gray argillitic schist. The strata are nearly everywhere vertical, and the strike is N. 40° E. Northward along the river there is no outcrop of rocks for several miles; but at the falls of the Cupsuptic a rock similar to the last is found. It differs from it in being of a darker color, somewhat more siliceous, and weathering with a pitted surface near where it comes in contact with an intrusive granite. Having seen a similar change elsewhere in the same kind of rock, under the same circumstances, it is more than probable that the granite was in some measure the cause of the change.

Sandstone Schist. Three miles north of Kennebago lake, on the Kennebago river, we find a sandstone schist. Although it often resembles a mica schist, yet nearly everywhere there is no doubt as to the character of the rock; and in some localities the fragments of which it is composed are a quarter of an inch in diameter, and very distinct, especially on the weathered surface of the rock. Elsewhere it has been greatly changed; and in some localities we find crystals of feldspar that have been produced since the sedimentation of the rock. This sandstone extends northerly some eight miles along the Kennebago river. On the mountain ridge north of Kennebago lake, where the sandstone first appears, the strata are nearly vertical, and the strike is N. 70° E.; but along the river the strike is more northerly. South of this great area of rock we have red and light gray argillites, and on the north we have diorite with serpentine. This sandstone schist is the rock on the boundary at the head waters of the Cupsuptic river, and it extends at least three miles southward along that stream; and the same rock outcrops on the Magalloway at Little Boys' falls north of Parmachena lake,—so that the area of this rock is exceedingly irregular in outline.

North-west of Kennebago lake, and extending south below the falls on the Kennebago river, there is an area of light gray, dark purple, and red argillites. The strata are vertical where observations have been taken; and there are sudden changes from one variety to the other. These argillites are probably the finer sediments derived from the great mass of material from which the sandstone schists were formed.

Diabase and Diorite with Serpentine. Diabase occupies an area on the Kennebago river. The most northern outcrop is about a mile from its mouth, and it extends a mile and a half northward along the river, and eastward towards Quimby pond. It is not altogether certain that this is a metamorphic rock. If only the southern outcrop had been seen, and the rock had been studied only in the field, we could have reached no other conclusion than that it was intrusive, yet other outcrops strongly indicate that the rock is metamorphic. At the head of one of the north-west branches of the Kennebago, which rises near the point where the boundary extends farthest southward, there is a fine-grained greenish rock, which would probably be distinguished as melaphyre by the German geologists. The area is limited here; but there are extensive outcrops on the boundary of New Hampshire, the summit of Mt. Carmel being composed of similar rock. The metamorphic diorite is one of the most interesting rocks found in this section of Maine. It outcrops on the Kennebago about twelve miles north of

Kennebago lake. Very few ledges are seen. The boulders, however, are large and numerous. But what is most important, it is undoubtedly the rock the *metamorphism* of which has produced the serpentine, which is also abundant here. The boulders of serpentine are first found in great numbers about ten miles north of Kennebago lake. They are enormous in size, sometimes 30 or 40 feet in length; and with these are boulders of diorite of nearly the same dimensions; but where the ledges appear, the diorite evidently passes into serpentine.

Argillitic Mica Schist with Staurolite. West of the gneiss containing limestone, in Phillips, we have a mica schist which, westward in Madrid, becomes quite argillaceous, and then again, in the south-west corner of Madrid and in Sandy River Plantation, and west as far as Rangeley lake, this rock has more the characteristics of a typical mica schist. The strata are everywhere vertical, or nearly so; and often there are beautiful crystals of staurolite. One of the finest outcrops with these crystals is at a school-house north of Sandy river, three and a half miles west of Madrid village. In the river, below the dam at Madrid village, there is a fine-grained, thickly-bedded mica schist, which contains concretionary nodules of granite from three inches to a foot in length, and from two to eight inches in width. In the larger ones the proportional width is much less than in the smaller ones. Five rods below the dam, the fissile adalusite schist has essentially the same strike and dip as the compact mica schist above. North-west of Madrid village there is a large area of ferruginous schists that probably belong to a different series of rocks from those we are considering. In the west part of Sandy River Plantation, and in the east part of Rangeley, we have mica schist with staurolite. This schist is extensively developed on Saddle-back stream, which flows near the Greenvale house. Following up this stream, we find, for nearly half a mile, both the schist and the conglomerate; and there is such an intermingling of the two, that, unless there have been great changes in the rocks since they were uplifted to their present position, they must belong to the same series of rocks. When the stream turns and comes more from the east, we leave the conglomerate. Above, a deep gorge has been cut in the schist along the strike. On the hill south-east of the Greenvale house, where the steep ascent begins, there is a mica schist with staurolite, and the dip is S. 20° E. 82°. There is a conglomerate included in this, and unconformable with it. On the face of the cliff it was not more than 120 feet in width, but it becomes wider as we ascend the hill. It dips N. 30° W. 75°, and stands on the upturned edges of the staurolite schist: so it is clear that we have two bands of conglomerate. Just south of the inlet of the lake, the schist and conglomerate have the same relations that they do on Saddle-back stream. This schist is more extensively developed in this section of Maine than any other rock, for, with some of the White Mountain gneisses and schists, it occupies the whole country to the north-east as far as Dead river in Flagstaff.

Rangeley Conglomerate. This conglomerate has given rise to much discussion, on account of the flattening and distortion of some of the pebbles of which it is composed, but its stratigraphical relations have received very little attention. This conglomerate is confined to a limited area, extending N. 30° E. and S. 30° W. from the inlet of

Rangeley lake. It is not far from a mile in width, but it becomes narrower northward, and in the middle of Dallas Plantation it is only a few rods in width. In the stream near the Greenvale house there seems to be, on the weathered surfaces, a marked difference between the staurolite schist and the conglomerate; but, breaking the conglomerate, every portion of it, except where there are actually pebbles, resembles in all respects the schist: even the staurolite is not wanting. Going across the stratification, we find places where there is an abundance of pebbles, and then they are wanting altogether, or have been so changed that they are not apparent. There are fine outcrops of conglomerate three quarters of a mile from Greenwich on the road to Rangeley, and at Moxey ledge, near the inlet of the lake. Some of the fragments at the former locality are a foot in diameter. The conglomerate on its north-west border, both north and south of the lake, passes gradually into a rock, which without a lens cannot be distinguished from common gneiss. Looking at this conglomerate now, as a whole, it has the appearance of having been formed from fragments derived from a rock which is now the argillitic mica schist with staurolite, before great metamorphic changes had taken place. The re-formed sediments, which are now the cementing material of the conglomerate, were so little assorted, that in the subsequent changes, in which both the conglomerate and the schist were involved, this material and the schist became essentially the same kind of rock.

Paleozoic.

Wrinkled Argillaceous Schist with hard Micaceous Bands. West of the conglomerate there is a broad area of rock, consisting chiefly of wrinkled argillaceous schists and a few hard micaceous bands. They are found on the hills south of Rangeley lake, and, north of the lake from where the conglomerate ends, it extends nearly to the outlet. In the east part of Rangeley it is limited northward near Gulf pond by an intrusive diorite, but, west, it extends about three miles north of Quimby pond. This band of rocks has one characteristic in common with some of the paleozoic rocks in New Hampshire: the veins of quartz by which it is penetrated, as well as those in the rocks immediately adjoining it, have a decidedly fetid odor. There is a band of this schist in the hill south-east of Greenvale: so it either extends around the Rangeley conglomerate, or there is here a repetition of the band to the west. The conglomerate mentioned as being found on this hill seems to be associated with this schist, rather than with the staurolite schist.

Lower Helderberg and Oriskany. There is quite a large area in the vicinity of Kennebago lake that most probably belongs to the Lower Helderberg and Oriskany. From their fossils, we are sure that some of the rocks belong to these groups. The area of Lower Helderberg and Oriskany in the vicinity of Parlin pond has been known for many years, and its limits on the south-west have been pretty clearly defined. The area in Flagstaff was pointed out for the first time by me at the Portland meeting of the Association for the Advancement of Science; and this now adds another to the many areas of these rocks already discovered.

Slates. There is a band of argillaceous rocks that are unlike, in their physical characteristics, any we have described, which is found on both sides of Kennebago lake. The most southern outcrop seen is on Spotted mountain, south of John's pond; the most northern, on Kennebago East mountain. The rock is generally thick-bedded. Sometimes it has the appearance of an argillaceous sandstone, and it is sometimes a little micaceous; and often the finest and most purely argillaceous bands pass suddenly into a slate conglomerate. The argillaceous rock on the ridge between John's pond and the south end of Kennebago lake breaks up into fragments more like shale than slate. The strike of this rock is N. 40° W.

Slate Conglomerate. The transition of the slate into conglomerate is so sudden that we do not suspect its presence until we see the boulders or ledges where the change occurs. Boulders of slate conglomerate are abundant on the southern shores of Kennebago lake, and outcrop in the vicinity of Flatiron pond.

Calcareous Sandstone with Fossils. Several years ago Mr. H. P. Dill found boulders of fossiliferous rocks along the river in Phillips; hence it has long been known that fossiliferous bands existed somewhere in this section. The rock seen in the vicinity of Kennebago lake is not the same as the boulders of Phillips, though further exploration may show that they are found here; but it seems more probable that the ledges from whence the Phillips boulders are derived are in some other locality, since the Phillips boulders are a pure sandstone, with fossils of Lower Helderberg types, while here the rock is a calcareous sandstone, with some fossils that are found with the Oriskany in the vicinity of Parlin pond. The change, however, does not appear to be any greater than it is between Parlin pond and Moose river. It has long been known that the line of demarcation between the Lower Helderberg and Oriskany in Maine is not so well defined as it is in New York. At Kennebago lake the number of species is quite limited, and they can scarcely be distinguished except upon the weathered edges of the rocks where some of them are well brought out.

The fossiliferous rocks here are probably limited to the area north of Spotted mountain between Flatiron pond and the bridle-path.

Glacial Drift. The study of drift in a region entirely covered by forests is more difficult, even, than the study of the ledges. In the vicinity of Rangeley lake, however, where there are farms, the absence of stratified drift is generally very noticeable. The most common boulders in the country about the east end of Rangeley lake are diorite; and these are derived chiefly from the numerous dykes in the west part of the town of Rangeley. There are very few boulders except of diorite on the bridle-path to Kennebago until we get within three miles of the lake, when we have those of slate conglomerate, calcareous sandstone, fossiliferous, and a few granite boulders.

About ten miles north of Kennebago lake, particularly on the west side of the river, we find a remarkable collection of boulders. They consist of sandstone schist, serpentine, and chlorite, with a few granite boulders; but as we go northward, the granite boulders increase, and soon they begin to predominate, and the others disappear altogether. Some of these boulders are of enormous size, and are probably derived from ledges in their immediate vicinity. There is another great collection of boulders on the Cupsuptic river below the gorge already referred to; and these are derived from the granite ridges on either side of the stream,—for, soon after we pass the granite ridges, these boulders disappear. Elsewhere no great collections of boulders were observed.

The drift striæ on Bald mountain, between Moosetocmaguntic and Rangeley lakes, are S. 55° E.; near Rangeley, on the south side and near the inlet, S. 35° E.; and on the high land south-east of Dodge pond, S. 65° E. The striæ here are in the direction of Saddle-back mountain.

Modified Drift, Kames, etc. A few gravel ridges in the west part of Dallas Plantation were the only gravel deposits resembling kames that were seen in the vicinity of Rangeley lake. On the lower part of the Kennebago river there are some well marked kames; and their absence was also noted on the river till we get about ten miles north of Kennebago lake, where there are some well marked ridges, but these do not extend more than two miles. On Cupsuptic river there is an almost entire absence of kames, as in the other regions we traversed; but on the lower part of the Cupsuptic, for six or eight miles, there are sand and gravel plains extending some distance from the river. These sand plains are characteristic, also, of the Magalloway; but, so far as our observation goes, they are wanting on the Kennebago.

ERUPTIVE ROCKS.

Granite. On the north-west branch of the Kennebago river, near its source, there is a band of granite probably two miles wide. It is a typical variety, consisting of quartz, feldspar, and mica in more nearly equal proportions than we often find them. There are, however, two kinds of feldspar, the triclinic being more abundant than it is commonly found in the coarser varieties of the New England granites. On the Cupsuptic river, in No. 4, R. 4, we find a similar kind of granite, which extends north and south nearly through the entire range. South-west, in No. 5, R. 1 and 2, there

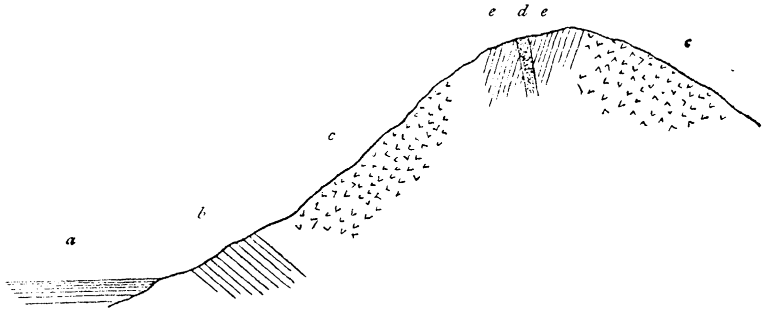

Fig. 64.—BALD MOUNTAIN.

a, the lake; *b*, schist on the border of the lake; *c*, granite; *d*, granite,—a narrow band near the top of the mountain; *e*, schist on the summit of the mountain.

are large areas of granite; but its greatest development we find on Observatory and Aziscohos mountains, and there is quite an extensive outcrop in No. 4, R. 1, on the south-west side of a hill north-west of the upper dam. The top of Bald mountain, between Rangeley and Moosetocmaguntic lakes, except its very summit, is composed of this same coarse granite. The way in which the schist is caught shows better the intrusive character of the Conway granite than any other example we have seen. Fig. 64 shows clearly this feature. To the left, on the border of the lake, we have the schist with an easterly dip; and as we ascend the mountain the granite suddenly appears, and extends almost to the very summit, which is crowned with the same kind of schist as that at the base; but in it is a well defined band of granite, about six feet wide, cutting it so sharply that the dip, which is westerly, is essentially the same as that of the mass on either side. South-east of Moosetocmaguntic lake, in township D on the head waters of Swift river, there is a band of granite, but it is a finer variety than those found northward.

Diorite. The most extensive outcrop of intrusive diorite found in New England has its southern limit near Gull pond, and outcrops are found for more than four miles to the north. South-east of Kennebago lake it forms a sharp mountain ridge, which rises more than 600 feet above the lake. The rock is generally a mica diorite, and it often contains garnets. On the southern limit of this diorite are fragments of schist; and it probably also penetrates the Paleozoic strata in the vicinity of Kennebago lake. There are many dykes of diorite in Rangeley immediately north of the lake, and the rock resembles the great outcrop northward, except that there is more hornblende and fewer garnets.

Felsite. The summit of the diorite ridge south-east of Kennebago lake is chiefly a compact feldspar; and one variety contains a few garnets and a little mica. This forms great cliffs near the summit of the ridge.

APPENDIX G.

THE ATLANTIC SYSTEM OF MOUNTAINS.

Want of time will prevent us from preparing a chapter upon the elevation of mountains and the occurrence of earthquakes, as promised in the preface to Volume I. In its stead, I will describe in greater detail the suggestion made upon page 6, Volume II, in regard to the distinctive features of the Atlantic system of mountains. I hardly need say there is a world-wide difference between the views of the age of mountains expressed in these reports, and those entertained by the metamorphic school of geologists. For this reason, it is important to set forth the correct history of the whole

Atlantic range, in the hope that the public will see that the name Appalachian ought never to be applied to any of the New Hampshire mountains.

The Atlantic system of mountains includes the high lands bordering the Atlantic ocean between Newfoundland and Alabama, bounded westerly by a depression readily traceable from the St. Lawrence and Hudson valleys to East Tennessee and northern Alabama. It may naturally be divided into three sections,—northern, middle, and southern, each entirely encircled by low land, if not the level of the sea.

The northern section is confined to Newfoundland, entirely surrounded by water. The culminating point is about 2,000 feet. The Nova Scotia elevation may be regarded as a branch.

The middle section, with a Green Mountain branch, is nearly encircled by tide-water, having the St. Lawrence gulf and river opposite a great portion, thence following the Champlain depression to the Hudson, the highest divide being 150 feet above the sea. From Albany to New York, and thence around to the starting-point, it is all tide-water. The culminating point is Mt. Washington, 6,293 feet.

The southern section is the longest and highest, reaching 6,700 feet in western North Carolina. The eastern boundary is washed by the sea; and the western is the great valley between the Hudson and Alabama.

The course of the Great Appalachian valley may be traced minutely thus: From the St. Lawrence to Lake Champlain is a rise of 90 feet. Sixty feet more brings us to the highest point in the depression between Lake Champlain and the Hudson river. The valley leaves the Hudson west of the Highlands, strikes across through northern New Jersey to the Kittatinny in Pennsylvania, 10 to 18 miles wide, and from 200 to 600 feet high. There is then a descent to the Potomac, and an elevation to the head of the Shenandoah. Continuing southerly, this valley rises to 2,595 feet at the highest part, near the sources of the Holston river. Following the great valley of Virginia, the altitude is 2,741 feet near the south line of the state, 898 at Knoxville, and 675 feet at Chattanooga. The highest part of this valley in Virginia does not correspond in latitude with the culmination of the mountains, as that point is reached in western North Carolina. This valley is regarded as the western boundary of the Atlantic system, and the eastern limit of the Appalachian ranges.

A section from East Virginia to Cincinnati crosses five different types of orographic structure. First, is the Atlantic plain, nearly 150 miles wide. No mountains exist in it. The elevations are those made by streams cutting into the Cretaceous and Tertiary horizontal deposits, which when protracted display crenulated edges. Second, are the elevations of the Atlantic system known as the Blue Ridge, with obtusely pointed summits. Third, is the valley of the Shenandoah. Fourth, are the long, narrow Appalachian ridges or the Alleghany Mountains. Fifth, is the elevated plateau, called collectively the Cumberland-Alleghany-Catskill plateau, with a quaquaversal arborescent drainage. The Hudson river, with its Mohawk tributary and the Susquehanna river, cut across all these five types of orographic structure.

Most authors call the Atlantic and Appalachian systems by this latter name only. I shall endeavor to show, from a study of their contours, their geological structure and composition, their separation by a great valley, and their identity with the Alps and Jura of Europe, that they are sufficiently diverse to be known by different names.

Distinctive Atlantic Features. These mountains occur as short, sharp ridges parallel to one another in echelon arrangement. Their summit lines are irregular, and their peaks obtusely pointed. The culminating points are higher than those of their neighbors, reaching 6,300 in the middle and 6,700 feet in the southern sections. The rocks are ancient gneiss of Eozoic age, Laurentian, Montalban, and Huronian, with commonly inverted dips. The periods of elevation were mostly pre-Silurian. On the west side of the Green Mountains of Vermont and the Blue Ridge in Virginia, a portion of the earth-masses included with other systems consists of Silurian sediments standing at high angles. These are so involved with the gneiss as to indicate an elevation in Middle Silurian times.

Distinctive Appalachian Features. Contrasting with the Atlantic elevations, the Appalachian ones occur in interminably long and narrow ridges, having level summits curving in the form of loops in the north, and terminating in pairs of straight ridges cut off short by faults in the south. Occasional gaps in them allow of the passage of roads. The elevation is usually 1,000 feet. The variation is from 800 to 2,500 feet; and in the Peaks of Otter in Virginia 4,000 feet is reached, in the neighborhood of the greatest elevation of the boundary valley. The rocks are altogether sedimentary, consisting of sandstones, shales, and a few limestones. They are curved, making the normal and symmetrical folds like a series of ocean waves. None of the dips are inverted. They are Paleozoic exclusively; and pebbles of the sandstone have often been derived from the breaking down of the crystalline schists of the Atlantic rocks to the east. The period of the elevation was at the close of Carboniferous time.

Connected with this is the great plateau, commencing in Alabama and Tennessee, or the Cumberland tableland, with a mean elevation of 2,000 feet, and a width of 30 to 40 miles. This is 3,000 feet high in Pennsylvania. It occupies a considerable breadth in central and southern New York, 2,000–2,600 feet high, and, highest of all in the Catskills, 3,800 feet. Here it terminates. It differs from the Appalachian mountains only in the smallness of the foldings, since in the coal plateau of Pennsylvania six basins, with the anticlinal arches between them, are described, and the same axes are prolonged northwardly into New York.

The Appalachians are divided along the Kenawha river in Virginia by a north-west-south-east fault, coinciding nearly with the highest part of the great valley. The Kenawha is the only one of the rivers flowing into the Mississippi valley that reaches and crosses the great valley. This break was produced by a great strain upon the crust, evidenced in the fall of the land northerly. It will be noted that the Atlantic mountains start with the culmination in North Carolina, and in northern Virginia divide, the one branch becoming the South Mountains in Pennsylvania, and the other sinks to the sea-level near Philadelphia. The low mountains of Staten Island indicate its place near New York. They rise into the White Mountains of New Hampshire beyond New York.

Then there was a sag along Hudson river, which may indicate the course of another break at the lowest part of the mountains just as the other fault shows itself along the Kanawha where the ge-anticlinal ridge is manifest.

Concerning the great valley, Lesley remarks that there is "an unbroken rim of Quebec and Laurentian from Georgia to the extreme eastern end of Canada, contrasted strongly with the plateau of the coal, commencing in Alabama and cut off square by the Hudson, the open valley of the Lower Silurians everywhere keeping the two systems apart."

In Europe, physical geographers refer the Alps and Jura mountains to different systems, characterized by features similar to those just indicated between the two portions of eastern America. The Alps correspond to the Atlantic, the Jura to the Appalachian, and the valley of Switzerland, prolonged into Bavaria and Moravia, to the great Appalachian valley. A section from Italy to the Rhine valley would be very much like the one in our country from eastern Virginia across to Cincinnati.

The Alps are composed of crystalline rocks centrally, with Carboniferous, Mesozoic, and Cenozoic groups corresponding to each other upon both sides. The structure is fan-shaped, but explained by supposing it to have been an anticlinal arch like a loop overhead, long since broken down and removed by denudation. The newer groups are arranged in close synclinal troughs, the older nearest the central crystallines, and consequently sometimes resting upon the newer ones by a species of inversion. The rocks of the Jura are largely Mesozoic, and are the best known exhibitions of the particular belts called for that reason the Jurassic. The Alps and Jura of America are therefore very much like their prototypes in Europe, in all essential particulars.

Authors have variously compared the American with the Swiss mountains. Guyot* says that the western portion is like the Jura,—adding that "there is one feature which distinguishes it [the Appalachian] from the Jura: it is the well-marked division into two longitudinal zones of elevation," or the ones distinguished above as Atlantic and Appalachian. The same author includes the Adirondack mountains with the Appalachians. J. D. Whitney† speaks of the Cordilleras (Pacific highlands) as like the Alps, and the Appalachian (Atlantic highlands leaving out Adirondacks) as like the Jura. The attempts of these distinguished authors to correlate our mountains with the Alps and the Jura, strengthens our conviction of the propriety of using special names for the chains corresponding to them so perfectly as do the two divisions mentioned south of the St. Lawrence.

That the name Appalachian is commonly used to include both these systems, is undeniable. My suggestion is, that we adopt an improved terminology, at least in geological treatises. Two or three considerations may be noted. 1. The desire for a single name to express the mountains along the eastern slope of the continent has led to the undue extension of the name Appalachian. But it should be remembered that, if it is used appropriately, it must include the Adirondacks and Labrador mountains also, for in the study of geography we are not to be confined to the limits of the United States. So far as appropriateness is concerned, we may as well include the Labrador as the White Mountains under the name Appalachian,—in fact, we must. Guyot, in his *Physical Geography* (1873), has perceived this difficulty in terms, and uses the name Atlantic highlands to include all the elevated region adjoining the eastern coast, and places the Adirondacks with the Appalachians, calling attention to the plain east of them. Harper's School Geography follows Guyot in using the terms Atlantic and Pacific highlands for the mountainous regions on the two sides of the continent. 2. The merging of these two systems under one name has been facilitated also by false theoretical notions. The advocates of the metamorphism of New England rocks legitimately assume the Atlantic to be of the same age with the Appalachians. If their doctrines were correct, this conclusion would follow. 3. The suggestion of the use of the term Atlantic for the eastern portion of this mountainous district is intended to be for geologists, not geographers. The eastern border will then have its Laurentian, Atlantic, and Appalachian systems of mountains formed in three separate sets of periods, the Eozoic, early and late Paleozoic. There will be further sub-divisions of these three systems developed as the subject is further studied.

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* *Amer. Jour. Science*, ii, xxxi, p. 166.

† Walker's *Physical Atlas*.

History of the Atlantic Mountain System.

The place of this system of elevation will be further appreciated after a brief sketch of the several important features of the physical history of the belt of land east of the Appalachian valley from Newfoundland to Alabama.

1. The original sediments of this area, now converted into rocks, were deposited in a basin of Laurentian rocks, the Adirondacks on the west, and near the coast an eastern line of similar age. The breadth of the eastern rim was greater at the south than in the north.

2. Precisely how far our porphyritic gneiss, Bethlehem and Lake Winnipiseogee groups are coeval with the Laurentian, is not certain; but it is clear that the Montalban rocks followed them, and that the first epoch of elevation occurred after their deposition. The first decided evidence of disturbance is afforded by the Franconia breccia.

3. The whole Huronian period next intervened. New Hampshire does not afford any evidence of elevation where the Montalban and Huronian rocks meet. The next upheavals were in connection with the disturbances accompanying the formation and intrusion of the Pemigewasset granites of Conway, Albany, and Chocorua, and the porphyry. This was evidently the epoch of greatest disturbance known in the White Mountains. It is to be compared with the elevation of the Green Mountains, where the Cambro-silurian formations have been folded and faulted.

4. There seems to have been, next, a submergence giving rise to the Gulf of St. Lawrence and to the Appalachian valley, unless this movement was connected with the Green Mountain elevation.

5. There was also a time of depression all over northern New England, to allow of the accumulation of Helderberg limestones. This was followed by,—

6. The last important elevation known in the White Mountains. The forces caused the Helderberg strata to be put into vertical and inverted positions. We have no evidence illustrative of the Appalachian revolution in the Atlantic district, unless it may possibly be represented by the smaller curvatures in the andalusite slates along the Mt. Washington carriage-road. Horizontal Devonian sandstones, resting upon inclined Helderberg strata along the eastern edge of the Atlantic district in Maine, fully confirm us in the belief that the Appalachian revolution, at the close of the Carboniferous period, was principally confined to the formations west of the great valley.

7. The changes in Mesozoic and Cenozoic times have diminished the size of the Atlantic mountains, so that they are scarcely recognizable between Connecticut and Virginia. The deposition of the Triassic sandstones would seem to have required a depression below the present level. Although no marine fossils occur in them, we must believe the basins to have had oceanic connections.

8. There must have been an elevation following the Triassic period sufficiently great to furnish the barriers for the Lower Cretaceous lake extending from eastern Long Island through New Jersey and a part of Pennsylvania. The former extension of the Hudson river channel 80 miles out to sea may have had some connection with the exit of the water from this Cretaceous lake.

9. A later depression is indicated by the presence of shallow water, 100 miles or so in width, between New Jersey and the Great Banks of Newfoundland. (See Pl. I, Vol. II.)

10. There must be added the changes of level described in the glacial and Champlain periods. Authors are not agreed as to their extent, while the current of opinion and the progress of discovery constantly tend to diminish their magnitude.

This review of the history of the Atlantic chain enables us to realize its magnitude, although the northern and middle sections are now partially submerged beneath the ocean.

APPENDIX H.

THE GEOLOGICAL MAP.

Not until the last moment has the geological map in the six atlas-sheets been completed. There are some small changes upon it from the statements of the text of Volume II, which are in all cases improvements. The north-west sheet shows for Quebec the elaborate subdivisions of the Huronian (Quebec), delineated by Sir. W. E. Logan, not yet published in the report of the Canadian geological survey, and kindly furnished us by A. R. C. Selwyn, the present director. From some familiarity with the country south, I have endeavored to carry the same classification into Vermont. I must except the Green Mountain gneiss, which Logan considered to be a metamorphic variety of the Sillery formation, overlying the Lauzon. As shown in my sections in the Vermont geological report (1861), this group everywhere underlies the Huronian, and is therefore older. With this exception, I find no fault with Logan's representation of the formations, but differ from him in placing the Lauzon below instead of above the Levis. Had I occasion to map the ground *de novo*, I should probably not use any of these terms. The limits of these groups have been stated upon page 463, Volume II.

I have elsewhere pointed out the anticlinal structure of the Green Mountains. This fact authorizes the deduction that the formations upon both its flanks are of more modern age, and that the Green Mountain gneiss is essentially Montalban, and underneath the Huronian. Essex county, Vt., is represented very differently from the delineations of the state geological map.

The additions to the Maine part of our sheets are entirely original contributions from our survey. Want of space prevents a description of the details south from the Androscoggin lakes.

I regret much not to have had sufficient time to incorporate all the observations of the position of strata throughout the state upon the map by appropriate symbols. The necessity of having every part of the work completed by a specified date has not given us sufficient time to perform this task. The conclusions to be derived from such delineations have been approximately presented in Pl. XXVI, Volume II.

The maps were executed by Julius Bien, of New York, and are not surpassed, for excellence of finish in the coloring or engraving, by any similar work heretofore issued in the United States.

APPENDIX I.

PANORAMIC VIEWS.

Allusion has been made in Volume I to a number of panoramic views taken from several of the White Mountain summits, by G. F. Morse, of Portland, Me. Owing to a change in the size of the Atlas, it was found necessary to re-draw these hand sketches, and they are all sketched upon two of the large sheets. Upon the first appear panoramas from Mt. Washington and Tremont, covering the entire horizon, divided into two parts by the points of compass. The upper begins at the west, and terminates at the east, the eye looking northerly. The lower view commences where the first leaves off, the eye being directed southerly. The same remarks apply to the panoramic views from Mts. Carrigain and Chocorua upon the second sheet. Both sheets also contain several other profile views, covering only a small part of the circuit, being designed to present the aspect of important or interesting ranges.

Another sheet has been prepared in a different style, by J. Rayner Edmands, with the help of a camera. This is like a photograph, reproducing nature exactly. A comparison of the two styles of profiles will suggest many interesting remarks.

The view from Monadnock is inserted by request, as it completely verifies the correctness of the scout Willard's report in 1725. He "saw Pigwackett lying one point from sd mountain and Cusagee mountain and Winnipesockey laying north East of sd Wannadnock." The mountains now called Pequawket, Kearsarge, and Gunstock may be seen in precisely the positions given by Willard. This fact indicates the correctness of the common application of the names Pequawket and Kearsarge. Within the past two years the people of North Conway and Bartlett are beginning to write the name of their mountain Kearsarge instead of Kiarsarge.

APPENDIX J.

DESCRIPTION OF A SHEET OF PROFILES TAKEN WITH A TOPOGRAPHICAL CAMERA.

BY J. RAYNER EDMANDS.

The topographical camera is a portable instrument, a modification of the old camera obscura, by the aid of which one may draw the forms of objects as seen from the point occupied, covering a large horizontal angle without distortion or variation of scale. A description of it will be found in *Appalachia*, Volume I, page 169.

In the summer of 1876, the writer, with the first instrument of the kind, visited several White Mountain summits, to test its performance, hardly expecting at first to obtain material of permanent value. When, therefore, the results proved worthy of publication, it became a matter of regret that they were so fragmentary in their nature; for no view had been drawn throughout the whole circle, and vacant foregrounds or hazy backgrounds rendered much of the work unavailable. During the following summer a few additional drawings were made; but, owing to unforeseen circumstances, the omissions of the year before were not generally supplied. It is also to be regretted that copies of the camera drawings have not been carried, for revision, to the points at which they were made. In presenting the profiles shown upon the accompanying plate in the Atlas, the writer is conscious that much remains undone which would materially improve their appearance, since he has rigidly adhered to the rule of showing nothing which does not appear on the original drawings, except that a few conspicuous omissions are supplied in dotted lines.

The accuracy with which the relative positions of objects can be drawn has been established by measurements upon independent profiles of the same subject, and also by comparison with the readings of a telescopic instrument. In some cases, haze or insufficient illumination may have caused the omission of lines or parts of lines; in some cases, subordinate lines may have been given undue prominence in making or copying the drawing; but in general the forms may be relied upon in considerable detail. No satisfactory means was originally devised, as a part of the instrument, for accurately locating the horizon upon the paper; but fortunately several of the points, at which the fullest or most interesting profiles were drawn, were also occupied by Prof. E. C. Pickering with the micrometer level, thus supplying the missing data without resort to extended calculations.

With the exception of that from Monadnock, the profiles are published on a scale of about five millimeters to the degree; but the scale attached to each is intended to compensate for unavoidable variations. To measure horizontal angles with the greatest attainable accuracy, use an ordinary metric scale; but in addition to the desired angle, measure with it the angular distance upon the attached scale between two graduations nearly under the two points. The difference between the nominal angular distance on the attached scale and its measured angular distance, as given by the scale used, should be applied, with the proper sign, as a correction to the angle measured upon the profile. Horizontal angles may be conveniently measured to tenths of a degree. For readiness of identification, the zero of the attached scale is made to coincide as nearly as may be with the south, so that its readings shall give directly the geodetic azimuth. The profile from Monadnock is on a scale of about one centimeter to the degree, or twice that of the others; but for the part of the view to the right of Belknap, the data are wanting for giving the precise scale. Also, the position of the horizon is not so well known for the second lines of profile from Monadnock and Starr King, as for the others. On the other hand, the distant view from Monadnock, extending between the Franconia and Ossipee ranges, has received more careful treatment than anything else upon the sheet.

Any identified point not on the sky-line may be found on the profile by means of its vertical position, given before the name. For this purpose, mark off from the zero of a short paper scale the distance between the horizon and the bottom of the profile, this distance being shown at either end of the sheet. Then, if this mark be placed anywhere upon the bottom line (the scale running in the direction of verticals), the zero will indicate the level of the occupied point; and the vertical position of the point sought may be read directly upon the scale.

For indicating minor points, and also those whose names are ambiguous or little known, it has been found expedient to use the notation adopted by the Appalachian Mountain Club, and described in *Appalachia*, Volume I, page 7. This consists of a capital letter followed by two numbers. The capital letter indicates one of twenty-six sections into which the state of New Hampshire has been divided; the number before the period indicates a certain mountain in the section; and the figure after the period indicates a special summit of the mountain, as indicated upon the maps of the club,—that is, different summits of the same mountain differ only in the last figure of the designation.

Distances, when given, are expressed in kilometres, the number being enclosed in brackets. One kilometre is a trifle less than five eighths of a mile.

Conspicuous unidentified points are arbitrarily lettered, for convenience in defining future identifications.

APPENDIX K.

PRELIMINARY RESULTS OF SECONDARY AND TERTIARY TRIANGULATION OF THE STATE OF NEW HAMPSHIRE,—1871-'76.

Furnished by Capt. C. P. Patterson, Superintendent of the U. S. Coast Survey.

The results are necessarily preliminary, for the reason that the field work is incomplete, and, in consequence, no final computation can be made at present. The positions of a large number of tertiary objects cannot at present be furnished, for want of a check computation.

NAME OF STATION.	LATITUDE.			LONGITUDE.			AZIMUTH.			BACK AZIMUTH.			TO STATION.	Distance—meters.
	°	′	″	°	′	″	°	′	″	°	′	″		
Mt. Pleasant, Me.	44	01	35.53	70	49	20.96	....			....			....	....
Agamenticus, Me.	43	13	23.18	70	41	31.88	173	19	33.1	353	14	09.5	Mt. Pleasant	89872.5
Gunstock	43	31	02.98	71	22	10.70	217	43	30.6	38	06	13.3	Mt. Pleasant	71681.5
							300	32	54.8	121	00	49.6	Agamenticus	63902.2
Uncanoonuc	42	58	58.34	71	35	18.83	249	36	13.6	70	12	58.6	Agamenticus	77686.6
							196	35	19.9	16	44	19.9	Gunstock	61992.1
Monadnock	42	51	39.61	72	06	30.49	219	13	05.9	39	43	26.3	Gunstock	94468.6
							252	07	58.4	72	29	13.0	Uncanoonuc	44548.7
Pawtuckaway	43	07	12.21	71	11	50.56	254	15	16.5	74	36	00.8	Agamenticus	42638.8
							64	34	35.7	244	18	34.4	Uncanoonuc	35323.2
Isles of Shoals	42	59	13.32	70	36	49.23	166	19	51.6	346	16	38.5	Agamenticus	26990.7
							107	27	45	287	03	50.4	Pawtuckaway	49791.5
Mason (or Barrett)	42	45	08.21	71	48	45.53	215	28	54	35	38	03	Uncanoonuc	31484.6
							116	37	36	296	25	33	Monadnock	27040.8
Crotched	42	59	52.57	71	52	26.70	274	00	50	94	12	31	Uncanoonuc	23342.5
							51	35	36	231	26	02	Monadnock	24441.3
Stewart	43	15	04.29	71	52	04.07	322	35	01	142	46	28	Uncanoonuc	37479.5
							24	25	12	204	15	20	Monadnock	47570.2
Rattlesnake	43	13	41.03	71	34	19.92	2	48	18	182	47	38	Uncanoonuc	27269.2
							96	12	34	276	00	25	Stewart	24143.6
Bean hill	43	23	47.97	71	32	48.91	226	50	33	46	57	52	Gunstock	19647
							4	13	33	184	11	50	Uncanoonuc	46089.7
(Kearsarge) now Kearsarge South Mountain	43	22	58.43	71	51	27.69	3	12	35	183	12	10	Stewart	14653.7
							266	25	06	86	37	55	Bean hill	25223.3
Stoddard	43	05	37.27	72	08	07.40	355	08	07	175	09	13	Monadnock	25939.5
							214	58	26	35	09	50	Kearsarge	39253
(Pequawket house, cupola—1851-'53), now Kearsarge North Mountain house	44	06	19.93	71	05	40.28	220	38	28.7	41	10	04.2	Mt. Blue	91493.6
							266	40	29.7	87	22	56.4	Sabattus	81424.9
Mt. Washington	44	16	12.99	71	18	12.91	3	39	13	183	36	28	Gunstock	83800.5
							304	57	50	125	17	56	Mt. Pleasant	47058.4
Croydon	43	28	53.68	72	13	11.36	290	22.6		110	37.5		Kearsarge	31299
							311	46.3		132	00.8		Stewart	38326
Cardigan	43	38	57.33	71	54	52.54	351	08.5		171	10.9		Kearsarge	29945
							53	02		232	49.4		Croydon	30901

Preliminary Results of Triangulation—continued.

NAME OF STATION.	LATITUDE.	LONGITUDE.	AZIMUTH.	BACK AZIMUTH.	TO STATION.	Distance—meters.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″		
Prospect	43 46 41.42	71 36 56.58	24 04.4	203 54.4	Kearsarge	48063
			352 30.5	172 33.3	Bean hill	42745
Cube	43 53 07.59	72 01 26.43	19 27.1	199 19	Croydon	47562
			289 48.4	110 05.3	Prospect	34931
Observatory hill (near Dartmouth college)	43 42 18.52	72 17 07.85	347 55.3	167 58	Croydon	25396
			226 19.4	46 30.2	Cube	29052
Moosilauke	44 01 23.08	71 49 54.97	45 17.9	225 09.9	Cube	21713
			9 07.2	189 03.8	Cardigan	42059
Ascutney	43 26 45.38	72 27 08.36	258 02.2	78 11.8	Croydon	19225
			205 00.9	25 07.8	Observatory hill	31791
Gile	43 47 19 57	72 21 07.12	342 36.1	162 41.5	Croydon	35754
			330 01.5	150 04.2	Observatory hill	10722
Moose	43 44 02.91	72 08 29.56	329 27.5	149 39.3	Kearsarge	45260
			74 31.9	254 25.9	Observatory hill	12040
Bald ledge	44 17 17.12	71 58 33.37	4 56	184 54	Cube	44900
			338 35	158 41	Moosilauke	31616
Whiteface	43 56 00.21	71 24 21.45	106 24.1	286 06.3	Moosilauke	35598
			44 25.9	224 17.2	Prospect	24119
Lafayette	44 09 37.83	71 38 41.03	44 32.2	224 24.4	Moosilauke	21397
			118 17.5	298 03.6	Bald ledge	30019
Black mountain	44 21 45.6	71 45 41.5	8 30.5	188 27.6	Moosilauke	38148
			64 13.3	244 04.3	Bald ledge	19004
Sunapee	43 17 56.2	72 03 50.7	288 21	108 29	Stewart	16792
			197 12.7	17 18.8	Cardigan	40752
Killington	43 36 16.3	72 49 14.4	285 30.3	105 55.1	Croydon	50438
			243 47.2	64 20.2	Cube	71349
Potato hill	44 07 12.7	72 56 12.3	289 17.7	109 55.7	Cube	77705
			256 00.7	76 40.9	Bald ledge	79023
Camel's Hump	44 19 09.6	72 53 13.1	205 36.3	125 12.4	Cube	84248
			272 25.1	93 03.2	Bald ledge	72776
Mansfield	44 31 34.4	72 48 55.9	218 06.2	138 39.3	Cube	95239
			291 17.7	111 52.9	Bald ledge	71915
Harris	44 12 21	72 19 33.5	325 41.3	145 53.9	Cube	43042
			251 46.6	72 01.2	Bald ledge	29411
Colton	43 57 09.1	72 22 03	219 54.8	40 11.1	Bald ledge	48702
			285 00.1	105 14.4	Cube	28573
Burke	44 34 13.8	71 53 36	11 51.8	191 48.3	Bald ledge	32060
			336 24.2	156 34.6	Lafayette	49676
Starr King	44 26 04.5	71 25 59.8	69 34	249 11.3	Bald ledge	46215
			29 03.7	208 54.9	Lafayette	34814
Mt. Washington—kitchenchy	44 16 13.5	71 18 10.8	92 19.8	271 51.6	Bald ledge	53749
			166 01.6	245 47.3	Lafayette	29911
Catamount	43 16 30.2	71 17 45	36 22.4	216 10.4	Uncanoonuc	40259
			77 00.1	256 48.7	Rattlesnake	23040
Trask hill	43 39 51.1	71 07 52.5	143 37.6	323 26.2	Whiteface	37189
			108 08.5	287 48.4	Prospect	41036

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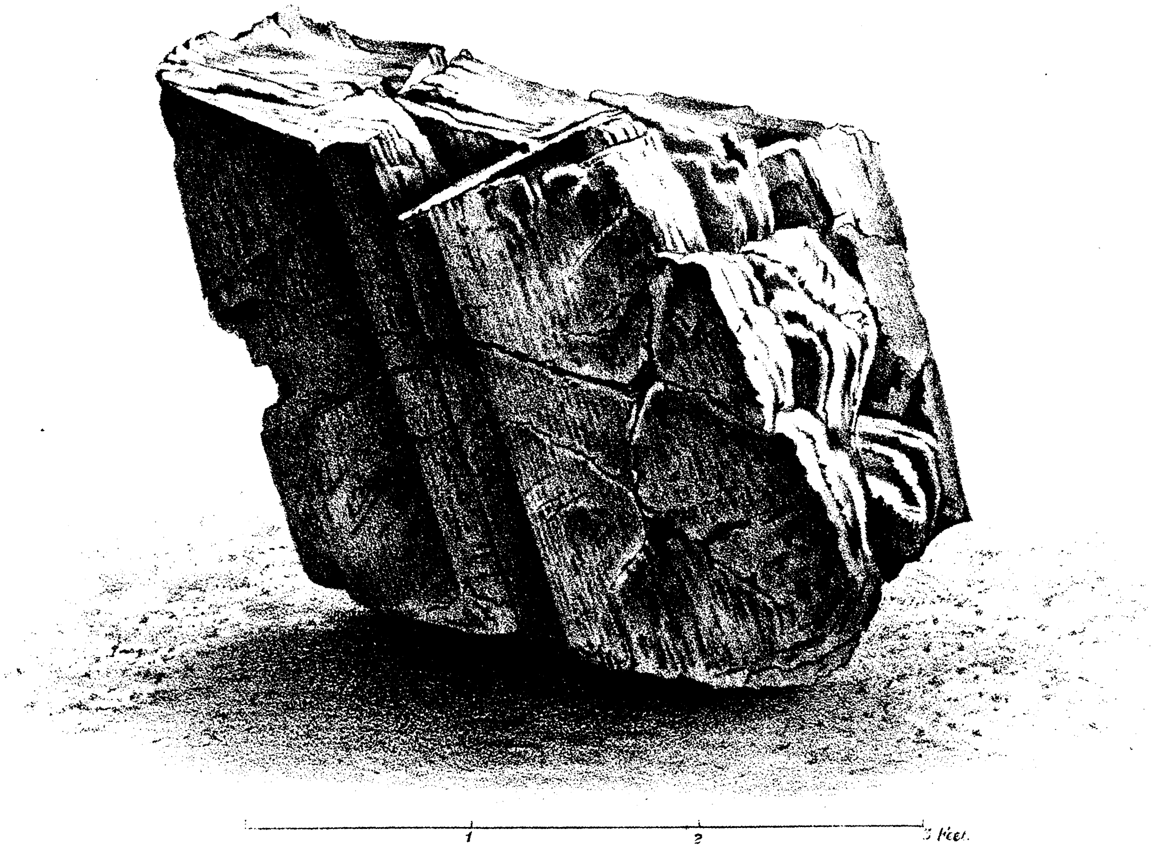

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